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A Report for the Wild Salmon Center

Pebble Mine Final Environmental Impact Statement (FEIS): Anticipated adverse impacts from the transportation corridor

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EXECUTIVE SUMMARY

Bristol Bay is one of the United States' last, largest remaining nearly undeveloped and roadless areas. That fact, combined with long-term, careful fisheries management; widespread occurrence of lakes and near-surface groundwater; and overall habitat quality, quantity, and complexity are what render Bristol Bay the largest sockeye salmon (*Oncorhynchus nerka*) producing watershed on earth (Rinella et al. 2018). Collectively, all nine subwatersheds of Bristol Bay produce about half of sockeye salmon globally (Ruggerone et al. 2010). The currently proposed Pebble Mine and its associated infrastructure straddles the two most productive subwatersheds within Bristol Bay: the Nushagak and Kvichak drainages which together produce about half of Bristol Bay salmon, or about one quarter of sockeye salmon globally (Ruggerone et al. 2010). While the majority of the currently proposed mine footprint sits in the Nushagak drainage, the vast majority of the approximately 132-km corridor necessary to transport mineral resources, chemical reagents, fuel, and other necessities for mining will be located in the Kvichak River drainage. Because of its focus on the mine footprint site itself as opposed to associated infrastructure, and the paucity of existing baseline data describing biota and their habitat that will be altered by mine infrastructure, the Pebble Project Final Environmental Impact Statement (FEIS) largely overlooks impacts of mine development to the Kvichak River watershed, including those likely to result from the preferred proposed road corridor. According to the EIS, the double-lane, unpaved road would include 105 culverts—37

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[1] Sarah O'Neal has over 20 years of international experience in freshwater ecology in salmon ecosystems, including over ten years of experience in Bristol Bay, Alaska, particularly in and near watersheds that will be impacted if the proposed Pebble Project is developed. She also has experience in other Alaska watersheds (Cook Inlet, Yukon, and Southeast Alaska transboundary rivers). Her expertise includes water quality, aquatic plants, diatoms, zooplankton, macroinvertebrates, resident and anadromous fishes, and interactions between them in both lakes and streams. She has worked in private, public, and non-governmental sectors. She has a Bachelor's Degree in Ecology, Evolution, and Conservation Biology from the University of Washington, a Master's Degree in freshwater ecology from the University of Montana's Flathead Lake Biological Station, and is currently a Ph.D. Candidate in the School of Aquatic and Fisheries Sciences at the University of Washington with research specific to toxicity of metals to salmonid fishes resulting from hard rock mining, assessment of sublethal and indirect ecological effects of mine waste, and methodological approaches to identifying salmon habitat. Sarah has participated in and now helps lead an eleven-consecutive year freshwater habitat monitoring program on and around the proposed Pebble Mine site and nearby drainages in the Nushagak and Kvichak watersheds. She has also conducted extensive reviews of Pebble Limited Partnership's Environmental Baseline Documents relating to freshwater fishes and food webs, as well as the US Environmental Protection Agency's Bristol Bay Watershed Assessment. Sarah's curriculum vitae collectively includes millions of dollars of grants, awards, and fellowships; multiple peer reviewed and dozens of other cited scientific publications; dozens of contributed and invited presentations to public, legislative, scientific, and other organizations; and countless interviews with and mentions in all forms of media.

of which would be designed for fish passage—and 17 bridges. Water would be extracted in yet undetermined volumes from 31 sites along the corridor to support construction and road maintenance (i.e., dust abatement) during mine and infrastructure construction and operation. During operation, the EIS predicts truck traffic would consist of 18 daily round trips, on which molybdenum concentrate would be trucked to the port site in from the mine, while fuel, mining reagents, and consumables would return to the mine site from the port. The EIS ultimately concludes that virtually all impacts to fish and their habitat from the transportation corridor will be temporary (defined as days to weeks) and limited to installation/construction (25 years). **To the contrary, roads have a legacy of long lasting and far reaching impacts on aquatic ecosystems worldwide.**

Given the subsistence, commercial, and recreational values of the Kvichak River watershed, the track record of environmental damage caused by roads in general, and the potential for toxic inputs from road use and accidents, this report reviews 1) Pacific salmon and other Bristol Bay fish ecology, life history, and global conservation status, 2) impacts from mining with an emphasis on impacts from the proposed Pebble Project preferred transportation corridor, and 3) the most glaring inadequacies of the EIS's habitat descriptions and predictions of impact from the mine access road. Collectively, this review resoundingly describes a systematic underestimation of impacts from the proposed transportation corridor to Bristol Bay (and particularly Kvichak River) fish populations.

PACIFIC SALMON POPULATIONS

GENERAL SALMON ECOLOGY

All Pacific salmon are anadromous, meaning they spawn and incubate in freshwater, but spend some part (usually the majority) of their lives rearing in the marine environment. Bristol Bay salmon are generally "semelparous," meaning they spawn once in their lifetime—generally within meters to kilometers of their birthplace—and subsequently die and decompose in freshwater. Variation in life history strategies both among and between species (e.g., freshwater and saltwater residence time, spawning location and timing, etc.) and variation in habitat use combine to produce several hundred discrete spawning populations (called salmon stocks) throughout Bristol Bay (Hilborn et al. 2003). Each stock is uniquely adapted to the subtleties of their own environment. This life history and genetic diversity, or "biocomplexity," is essential to the long-term sustainability of salmon populations as a whole. With inevitably varying environmental conditions, decreases in some stocks are buffered by increases in others. This phenomenon is often referred to as the "portfolio effect," analogous to diverse financial stock portfolios which successfully weather downturns in some stocks with upticks in others (Schindler et al. 2010; Reeves 2020). Consequently, maintenance of salmon biocomplexity by way of maintaining natural environmental conditions are essential to the conservation of Pacific salmon.

Multiple annual spawning runs comprised of five Pacific salmon species during various times of year add up to thousands to millions of returning salmon in Bristol Bay rivers. Because most of their growth occurs in the ocean, spawning and decaying adult salmon introduce massive influxes of marine-derived nutrients to the otherwise nutrient limited watersheds in the area.

Consequently, the entire Bristol Bay ecosystem is heavily dependent on returning salmon and their marine-derived resource pulses (Cederholm et al. 1999, Gende et al. 2002). In Bristol Bay, sockeye salmon (*Oncorhynchus nerka*) in particular are a keystone species, meaning they are amongst the most significant determinants of the structure, function, and dynamics of that ecosystem. Because of the sheer numbers of sockeye that return to Bristol Bay on an annual basis, trout, char, other resident fishes, bears, and hundreds of other aquatic, terrestrial, and avian species rely heavily on their subsidy in the form of eggs, flesh, and nutrients released as they decay (Willson and Halupka 1995, Cederholm et al.1999, Gende et al. 2002; Figure 1, Table 1.). Because sockeye are a (if not *the*) primary driver of biological productivity in Bristol Bay watersheds, any significant reduction in sockeye returns will have cascading effects throughout entire aquatic and terrestrial food webs (Figure 1).
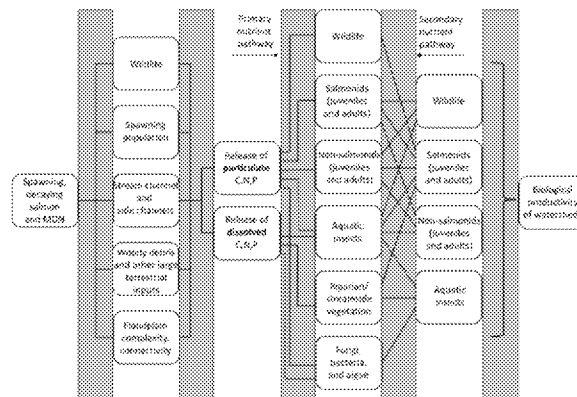
Figure 1. The influence of sockeye salmon as a keystone species on Bristol Bay watersheds. Adapted from Cederholm et al. 1995. MDN are marine derived nutrients (nutrients that salmon deliver from their growth in the North Pacific Ocean to their natal spawning habitat in freshwater headwater to mainstem streams and rivers). C is carbon, N is nitrogen, and P is phosphorus. C, N, and P are fundamental building blocks to all life. From Cederholm et al. 1999.

In the freshwater environment, sustainable salmon runs require complex, connected habitats that vary across space (e.g., from the reach, to the stream, to the watershed scale) and time (Whited et al. 2012, Brennan et al. 2019). Salmon spawning requires clean cold water, unbound gravel to cobble-sized riverbed material, and unimpeded groundwater and surface water interactions. After spawning, eggs typically incubate over winter, often relying on groundwater inputs throughout their global range, but particularly in harsh northern environments where surface waters freeze (Reynolds 1997). In the spring, "fry" hatch from eggs at which point they may migrate immediately to the sea (e.g., pink and chum salmon) or remain in a variety of freshwater environments (e.g., Chinook, silver, and sockeye salmon). Fry remaining in freshwater mature into "parr," which rely heavily on freshwater zooplankton or aquatic and terrestrial insects for food. Instream habitat complexity and connectivity are essential to providing ideal foraging and predator avoidance conditions. Parr may remain in freshwater from less than one a year or up to at least four years, at which time they become "smolts" on their seaward migration. Smoltification is a highly complex process involving physiologic changes in body shape and osmoregulation (maintenance of salt and water balances across cell membranes). Once at sea, smolts gain the vast majority of their body weight (>90%) during their one to several year marine residence. Upon maturation, adult salmon return to their natal streams, delivering large marine-derived nutrient pulses often to otherwise nutrient-poor environments (Figure 2).
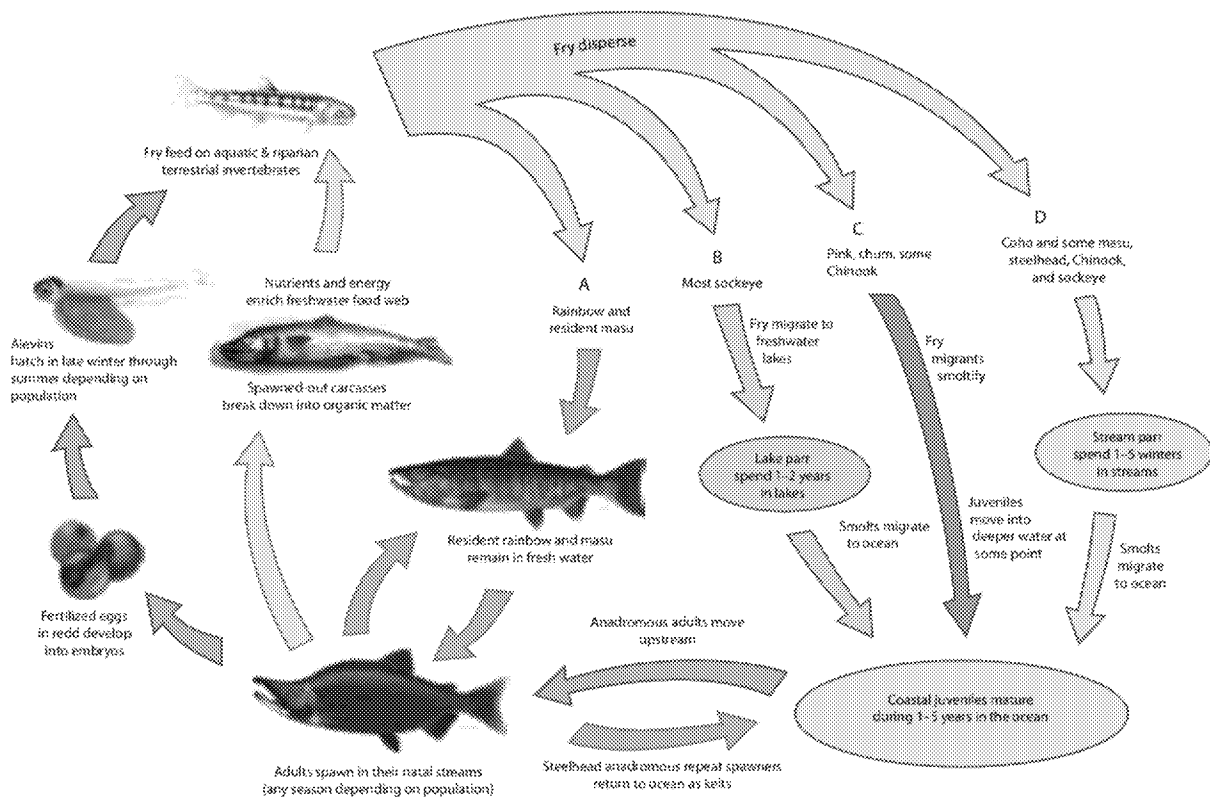
Figure 2. Salmon life cycles. From Chambers et al. 2012, © Kate Spencer.

PACIFIC SALMON LIFE HISTORIES

Sockeye salmon (*Oncorhynchus nerka*)

Sockeye (or red) salmon typically spawn in July and August. After incubating over winter, most juveniles emerge in spring and generally spend at least one year rearing in freshwater lake habitat before outmigrating to the marine environment. Some juvenile sockeye rear in streams before smoltification ("river-rearing"), while others migrate to sea immediately after emergence. Smolts leave the system in spring and may spend anywhere between six months (in the case of male jacks) to three years in the ocean, returning between the ages of 3 and 6 years old (Figure 2). One or more life stages of sockeye salmon inhabit Bristol Bay watersheds during all months of the year, though this is not clearly reflected in the EIS (Johnson and Blossom 2019; Figure 3).

Chinook salmon (*Oncorhynchus tshawytscha*)

Chinook salmon spawn the earliest of the Pacific salmon species, typically from July to early September. After incubating over winter, juveniles emerge in spring and typically spend one year rearing in tributaries or in mainstem habitats. Smolts leave freshwater in April or May before returning to spawn mostly as 5-yr-old or 6-yr-old fish (Groot and Margolis 1991; Figure 2).

Consequently, one or more life stages of Chinook salmon inhabit Bristol Bay watersheds during all months of the year, though this is not clearly reflected in the EIS (Figure 3).

Coho salmon (*Oncorhynchus kisutch*)

Coho (or silver) salmon spawn the latest of the Pacific salmon species, with peak spawning typically in August and September. Spawning may begin as early as July and at least last as late as November. After incubating over winter, juveniles emerge in spring and generally spend one to three years rearing typically in tributary or off-channel habitats (e.g., side channels, springbrooks, etc.). Smolts leave the system in spring and may spend anywhere between six months (for undersized, but sexually mature males known as "jacks") to 18 months (more commonly) in the ocean (Groot and Margolis 1991; Figure 2). One or more life stages of coho salmon inhabit Bristol Bay watersheds during all months of the year, though this is not clearly reflected in the EIS, though this is not clearly reflected in the EIS (Figure 3).

Chum salmon (*Oncorhynchus keta*)

Chum (or dog) salmon spawn in fall. After emerging in spring, they begin their seaward migration within days to weeks. At sea, chum spend 3-4 years before returning to their natal habitat to spawn (Figure 2). Consequently, chum salmon are present in Bristol Bay watersheds from fall to spring, though this is not clearly reflected in the EIS (Figure 3).

Pink salmon (*Oncorhynchus gorbuscha*)

Unlike other Pacific salmon species, pink (or humpy) salmon complete their life cycle in two years. In doing so, they create two genetically distinct populations of odd and even year spawners within one river system important to maintaining the overall sustainability of pink salmon populations (Groot and Margolis 1991). Pink salmon typically spawn between late June and mid-October. After incubating over winter, fry emerge in spring and immediately migrate downstream to the marine environment. They spend about a year and a half in the ocean before returning at the age of two (Figure 2). Consequently, one or more life stages of pink salmon inhabit Bristol Bay watersheds for most of the year though this is not clearly reflected in the EIS (Figure 3). Although the FEIS indicates pink presence only from April through September in Bristol Bay watersheds (Figure 3), it overlooks incubation which extends through from late fall to early spring (including October through March).

Table 1. Some of the dozens of vertebrates and hundreds of macroinvertebrates that consume salmon. Modified from Willson and Halupka 1995, Cederholm et al. 2000, and Nakajima and Ito 2003.

	Salmon Life-History Stage		
Consumers	Eggs	Juveniles	Adults
Mammals		Mink (*Mustela*) River otter (*Lutra*)	Beluga whales (*Delphinapterus*) Black-tailed deer (*Odocoileus*) Brown and black bears (*Ursus* spp.) Cougar (*Felis*) Coyote (*Canis*) Deer mouse (*Peromyscus*) Flying squirrel (*Glaucomys*) Humpback whales (*Megaptera*) Killer whales (*Orcinus*) Mink Raccoon (*Procyon*) Red fox (*Vulpes*) Red squirrel (*Tamiasciurus*) Sea lions (*Eumetopias*) Seals (*Phoca*) Shrew (*Sorex*) Weasels (*Mustela*) Wolf (*Canis*)
Birds	American Dipper (*Cinclus*) American robin (*Turdis*) Canada goose (*Branta*) Fox sparrow (*Passerella*) Goldeneyes (*Bucephala* spp.) Gulls (>4 *Larus* spp.) Hooded merganser (*Lophodytes*) Mallard (*Anas*) Song sparrow (*Melospiza*) Spotted towhee (*Piplio*) Varied thrus (*Ixoreus*)	Arctic tern (*Sterna*) Belted kingfisher (*Megaceryle*) Black-billed magpie (*Pica*) Great blue heron (*Ardea*) Gulls Loons (*Gavia*) Mergansers (*Mergus* spp.) Murre (*Uria*) Osprey (*Pandion*) Ravens and crows (*Corvus* spp.) Scaup (*Aythya* spp.)	Bald eagle (*Haliaeetus*) Black-billed magpie Gulls Northern harrier (*Circus*) Osprey (*Pandion*) Ravens and crows Red-tailed hawk (*Buteo*) Sharp-shinned hawk (*Accipiter*) Steller's jay (*Cyanocitta*) Winter wren (*Troglodytes*)
Fishes	Coho salmon (*Oncorhynchus*) Dolly Varden (*Salvelinus*) Grayling (*Thymallus*) Sculpins (*Cottus* sp.) Suckers (*Catostomus*)	Coho, Chinook salmon Cutthroat trout Dolly Varden Pacific herring (*Clupea*) Rainbow trout/steelhead Sculpins Walleye pollock (*Theragra*)	Gobiid (*Gymnogobius*)

Table 1 (cont'd). Some of the dozens of vertebrates and hundreds of macroinvertebrates that consume salmon. Modified from Willson and Halupka 1995, Cederholm et al. 2000, and Nakajima and Ito 2003.

	Salmon Life-History Stage		
Consumers	**Eggs**	**Juveniles**	**Adults**
Aquatic insects			Beetles (Coleoptera order) Caddisflies (Trichoptera order) Isopods (Isopoda order) Leeches (Hirudinea subclass) Mayflies (Ephemeroptera order) Midges (Chiroomidae family) Other flies (Diptera order) Scuds (Gammariedae family) Snails (Gastropoda subclass) Stoneflies (Plecoptera order) Worms (Oligochaeta subclass)

OTHER FISH POPULATIONS

RAINBOW TROUT (*Oncorhynchus mykiss*)

Rainbow trout exhibit the most diverse life history of all Pacific salmon. Unlike other Pacific salmon (genus *Oncorhynchus*) species, rainbow trout spawn in the spring (typically March to July), emerging as juveniles weeks to months later in the summer (Groot and Margolis 1991), and frequently spawn multiple times in their lives (known as "iteroparity"). Within freshwater, Bristol Bay rainbow trout can be lake residents, stream residents, or migratory between lakes and streams. Bristol Bay rainbow trout are documented migrating over 50 km (about 30 mi) within streams, and over 100 km (about 60 mi) between rivers and lakes (Meka et al. 2003). They occur throughout Bristol Bay watersheds and tend to mature slowly and grow to relatively large sizes (Russell 1977). Their large size is likely related to heavy feeding on abundant sockeye eggs during the summer sockeye spawning period (Scheuerell et al. 2007). Their large size makes them a world class recreational fish species. They are also used in subsistence harvests (Woody 2018).

Species[1]	Life-Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Chinook salmon	Adult Migration												
	Spawning[3]												
	Fry Emergence												
	Juvenile Rearing												
	Outmigration												
Coho salmon	Adult Migration												
	Spawning[3]												
	Fry Emergence												
	Juvenile Rearing												
	Outmigration												
Sockeye salmon	Adult Migration												
	Spawning[3]												
	Fry Emergence												
	Juvenile Rearing												
	Outmigration												
Chum salmon	Adult Migration												
	Spawning[3]												
	Fry Emergence												
	Juvenile Rearing												
	Outmigration												
Pink salmon	Adult Migration												
	Spawning[3]												
	Fry Emergence												
	Juvenile Rearing												

Figure 3. Estimated life-stage periodicities of Pacific salmon in streams draining the Pebble Mine footprint (North Fork Koktuli River, South Fork Koktuli River, and Upper Talarik Creek). Modified from FEIS, Table 3.24-5, p. 3.24-27. Footnote [1] indicates: Unless otherwise noted, periodicities taken from project baseline data documents or ADF&G recommendations. Footnote [3] indicates: egg and alevin incubation extends from beginning of spawning to end of fry emergence (according to USACE). The original figure visually excludes salmon incubation and emergence, which appears misleading. Because egg and alevin incubation are virtually overlooked by USACE, red rectangles indicate incubation and emergence time in rivers draining the Pebble deposit (red fill added to USACE figure).

DOLLY VARDEN (*Salvelinus malma*)

Dolly Varden also exhibit diverse life histories. In general, Dolly Varden spawn in the fall between September and November. Like rainbow trout, Dolly Varden can spawn multiple (typically no more than three) times during their lives. Fry emerge in early spring. Juveniles can remain in streams, migrate to lakes, or migrate to sea. All life stages of Dolly Varden inhabit freshwater environments during all months of the year, and are ubiquitous in headwater streams of Bristol Bay (Woody and O'Neal 2010). Dolly Varden may remain in small streams as residents, migrate within freshwater systems (at least up to 60 km, or about 40 mi), or migrate widely between major western Alaskan watersheds via marine pathways (over 500 km, or about 300 mi) (Lisac 2009). Closely related Arctic char (*Salvelinus alpinus*) and lake trout (*Salvelinus namaycush*) also occur in Bristol Bay watersheds. All three species are important subsistence and recreational fishes.

OTHER HARVESTED FISHES

- **Arctic grayling** (*Thymallus arcticus*) are widespread throughout Alaska and Bristol Bay. They spawn in spring and migrate extensively in freshwater between spawning and feeding locations which may be in rivers, tributaries to lakes and rivers, and intermittent streams (Woody 2018). They are important subsistence and recreational fish.
- **Humpback whitefish** (*Coregonus pidschian*) can be lake residents, stream residents, migratory between lakes and streams, or anadromous (Woody 2018). They are long lived (documented up to 57 years), can migrate up to 1,300 miles to rock, gravel, or sand dominated spawning sites, typically in late fall. Humpback whitefish are part of the "*Coregonus clupeaformis* complex" of whitefish species which inhabit Lake Clark, the Newhalen River, the Chulitna River basin, and Lynx Creek near the proposed mine and road corridor sites. Little is known about their distribution in other areas of Bristol Bay (Woody 2018). Humpback whitefish in particular, and some other whitefish species are important subsistence fishes, especially near the Pebble Deposit (Power 1978, Woody 2018).
- While invasive in other Alaskan watersheds, **Northern pike** (*Esox lucius*) are native to Bristol Bay tributaries and much of northern North America. Northern pike are generalist feeders (eating both insects and fish). Where they are introduced, they prefer salmon as prey, and may potentially eliminate salmon populations (Sepulveda et al. 2015). In their native habitat like Bristol Bay, however, they feed on insects and multiple fish species, thereby cohabiting with salmon (Cathcart et al. 2019). They are important subsistence and recreational fish.
- **Suckers** (family *Catostomidae*) are slow-growing, long-lived fishes that spawn in spring and emerge as larval fish about a month later. They can be relatively sedentary in freshwater, or migrate hundreds of kilometers (over 60 mi) in a year, and up to 60 km (about 35 mi) in a day. They are important subsistence fishes.

OTHER RESIDENT FISHES

- **Lampreys** (family *Petromyzontidae*) that inhabit Bristol Bay watersheds most likely include Pacific (*Entosphenus tridentatus*), Arctic (*Lethenteron camtschaticum*), and brook (*L. alaskense*) lamprey (Mecklenburg et al. 2002). All three species are highly migratory,

whether within freshwaters or between freshwater and marine environments. They typically spawn in large groups in gravel-bedded rivers in spring. Although frequently parasitic, they are not detrimental to fish populations (Wiedmer 2014). Lampreys are consumed by rainbow trout, over a dozen bird species, and a variety and mammals (Wiedmer 2014). While targeted as subsistence fishes in the Yukon drainage and many Pacific Northwest watersheds, they are not a focus of subsistence harvest in Bristol Bay (Wiedmer 2014).

- **Alaska blackfish** (*Dallia pectoralis*) are native only to western Alaska and Russia's Chukotka Peninsula (Mecklenberg et al. 2002). Their esophagus is modified as an accessory respiratory organ, allowing them to breathe air, and also to tolerate extremely low dissolved oxygen levels (Sisinyak 2006). Alaska blackfish were historically a much more important subsistence species than they are now, and they are not targeted in recreational fisheries (Wiedmer 2014).

- **Sculpins** (genus *Cottus*) are virtually ubiquitous in Alaska's salmon streams, and are the most abundant fishes in streams draining the Pebble deposit (Woody and O'Neal 2010). Their range extends across the entirety of North America. They inhabit diverse habitats, though prefer cool, clean waters. In Bristol Bay, they feed heavily on sockeye salmon eggs (Foote and Brown 1998). They are likely the most sedentary (least migratory) of all abundant fish species in Bristol Bay and consequently are useful as potential early indicators of sublethal and/or chronic contamination and habitat degradation. They are also important food for Arctic grayling, burbot (*Lota lota*), rainbow smelt (*Osmerus mordax*), humpback whitefish, lake trout, Arctic char, Northern pike, rainbow trout, other whitefish, and other fish species (Wiedmer 2014). Sculpins are not harvested in subsistence or recreational fisheries, but are a critical component of Bristol Bay freshwater food webs.

- Multiple other resident species inhabit Bristol Bay watersheds and are also play critical roles in Bristol Bay food webs including various smelts (family *Osmeridae*), other whitefishes, burbot, and sticklebacks (family *Gasterosteidae*).

BRISTOL BAY FISHES IN A GLOBAL CONSERVATION CONTEXT
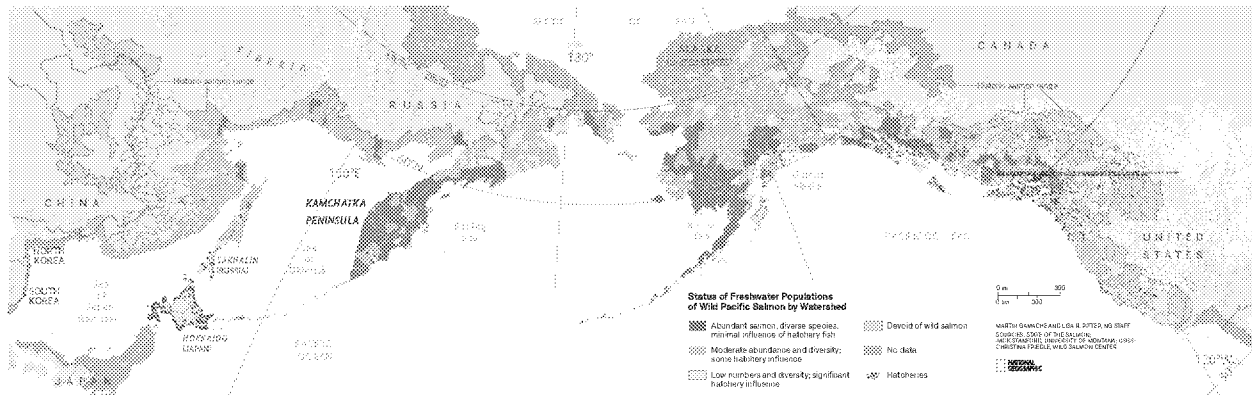
PACIFIC SALMON

Globally, Pacific salmon suffer from widespread population extinctions and declines. Between 100 and 400 distinct salmon populations are estimated extinct around the North Pacific (Nehlsen et al. 1991, Augerot 2005, Gustafson et al. 2007). Vulnerability by species shows some association with the amount of time spent in freshwater. For example, populations that spawn in interior locations further from the ocean have experienced more declines than their conspecific coastal populations, and species that spend more of their lifecycles in freshwater habitat (Chinook, steelhead) have declined more than their marine oriented counterparts (pink and chum; Rinella et al. 2013). Generally, population extinctions and declines are greater with decreasing latitude (Figure 4). In addition to other development impacts, evidence abounds that warming temperatures are causing further declines in salmon and trout ranges.

Sockeye salmon

Two US sockeye populations are listed as threatened or endangered under the US Endangered Species Act (ESA) (Rinella 2013), ranging from Idaho to Washington (Augerot 2005). Other

significant populations occur in British Columbia's Fraser River, and collectively amongst other Alaska streams. Bristol Bay produces about half of global sockeye salmon returns (Ruggerone et al. 2010). The Fraser River has experienced significant population declines and harvest closures in recent decades due habitat degradation and other factors, and supports about a quarter of Bristol Bay's populations on average (O'Neal and Woody 2011). Within Alaska, all non-Bristol Bay sockeye populations combined produce fewer average returns than Bristol Bay (Figure 5, Rinella 2013).


Figure 4. Status of wild Pacific salmon populations by watersheds throughout their native range. Blue indicates abundant salmon with diverse species and minimal influence of hatchery fish; green indicates moderate abundance and diversity of salmon with some hatchery influence; yellow indicates low numbers and diversity of salmon with significant hatchery influence; orange indicates watersheds devoid of salmon; and gray indicates watersheds without sufficient data to determine status. Red dots indicate locations of hatcheries. Photo courtesy of National Geographic.

Despite USACE comparisons of Bristol Bay with other Alaska watersheds like Cook Inlet and the Copper River sockeye harvests commonly experience emergency closures due to failure to meet management goals (e.g., Welch 2020; Figure 5). For example:

> Other salmon fisheries in Alaska exist in conjunction with non-renewable resource extraction industries. For example, the Cook Inlet salmon fisheries exist in an active oil and gas basin and have developed headwaters of Anchorage and the Matanuska-Susitna areas. The Copper River salmon fishery occurs in a watershed with the remains of the historic Kennecott Copper Mine and the Trans Alaska Pipeline System in the headwaters of portions of the fishery. (FEIS, Executive summary p. 86). Moreover, their sockeye (and other salmon species) production pales in comparison to Bristol Bay's.

Chinook salmon

Ten US Chinook salmon populations ranging from California to Washington are listed as species of concern, threatened, or endangered under the US Endangered Species Act (ESA) (USEPA 2014). Although no Chinook populations in Alaska are listed as threatened or endangered under the ESA, emergency harvest closures are common in all major watersheds with notable subsistence and commercial harvest implications. While Alaska's Kuskokwim and Yukon Rivers and Canada's Fraser River remain significant global producers of remaining wild Chinook salmon, Bristol Bay's Nushagak River is frequently the largest producer of wild Chinook salmon in the eastern Pacific Ocean (Figure 6).
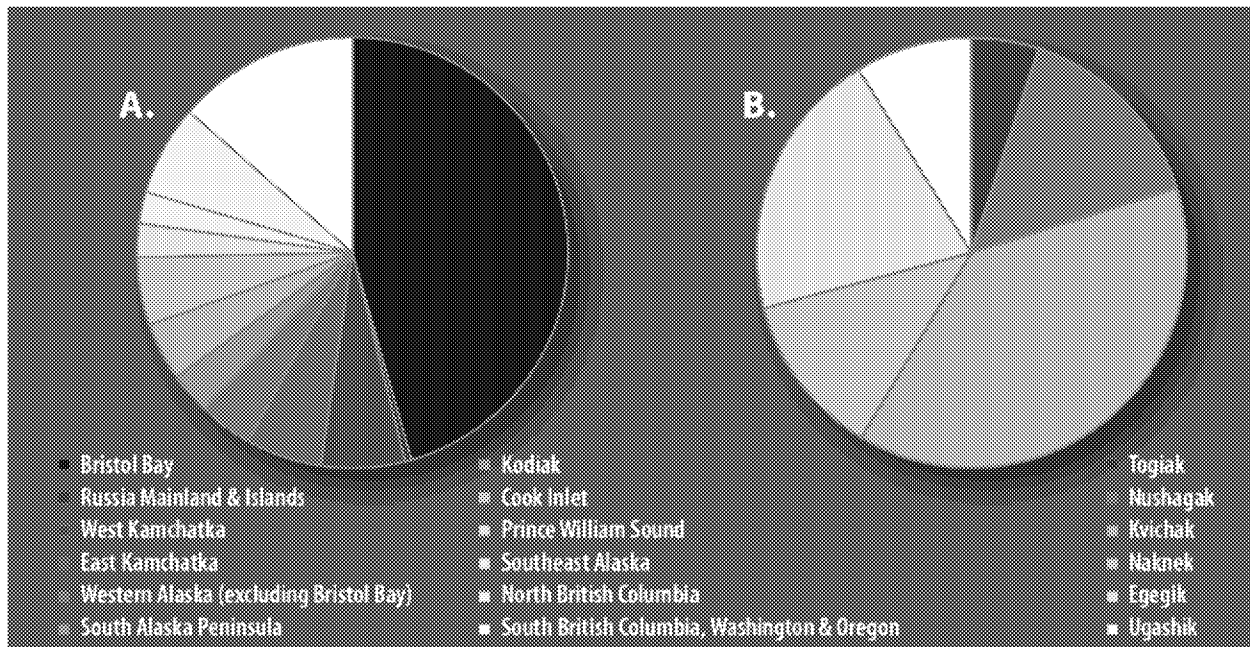
**Figure 5.** Proportion of sockeye salmon runs A) on a global basis and B) within Bristol Bay. Table from EPA 2014.

Coho, chum, and pink salmon

Five coho salmon and two chum salmon populations ranging from California to Washington are listed as species of concern, threatened, or endangered under the ESA (USEPA 2014). There are no ESA listings for coho, chum, or pink salmon in the State of Alaska. Consequently, Bristol Bay's populations of all three species are globally important in light of their status elsewhere (Figure 4). Juvenile coho salmon are the most commonly found salmon species in the Bristol Bay and road corridor footprint, and the second most common fish species collected before adult salmon return to spawn (Woody and O'Neal 2010).

TROUT AND OTHER RESIDENT FISHES

Other harvested fishes

- Bull trout—a species closely related to Alaska's Dolly Varden, Arctic char, and lake trout—occur in less than half their historic range in the western contiguous US and are listed as threatened under the ESA throughout their US range. It is estimated with continued development compounded by climate change, as much as 99% of their habitat could disappear within 50 years (Rieman et al. 2007). Dolly Varden population status is virtually undocumented in Alaska, though qualitative data indicate widespread distribution (AFFI 2020).
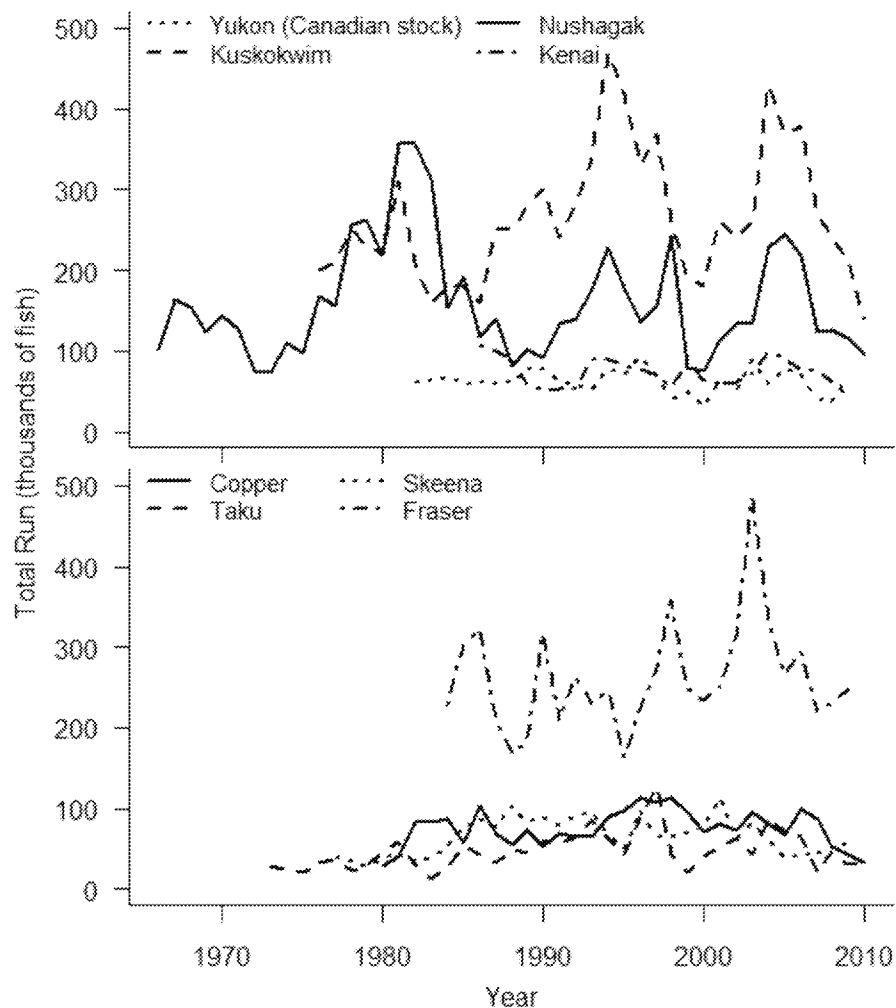
Figure 6. Chinook salmon abundances for eastern Pacific river systems from 1966-2010. From Rinella et al. 2013.

- Rainbow trout (*Oncorhynchus mykiss*) are the most widely introduced fish species in the world. Rainbow trout are flexible in life history strategies (ranging from ocean-going fish known as steelhead, to entirely freshwater residents known as rainbows), resilient because of their life history flexibility, and persistent beyond their native range (Behnke 2002). In spite of that, all six entirely freshwater dwelling native subspecies of contiguous US rainbow trout are of conservation concern (Katz et al. 2013). While quantitative information is lacking, Bristol Bay is home to one of the world's last remaining, genetically pure populations most closely reflecting historic conditions (Arostegui, M., personal communication, July 2020).
- Arctic grayling (*Thymallus arcticus*) in the contiguous US have experienced population declines largely due to replacement by nonnative trout species and habitat degradation (Behnke 2002). Michigan grayling are extinct while Montana grayling populations have

declined to the extent they warranted consideration for federal ESA listings (Lamothe and Petersen 2007, USFWS 2010a).

- Whitefish (*Coregonus* sp.*, Prosopium* sp., and others) are important subsistence species and their populations have experienced significant declines and extinctions in the Great Lakes, though are not documented as having any status of conservation concern west of the North American Continental Divide (Behnke 2002). Because whitefish are not popular commercial or sportfish, very little information on their distribution, population, and conservation status are available.

Other resident fishes

- Pacific Lamprey (*Lampetra tridentata*) have cultural and ecological significance but have also experienced steep declines in abundance and range contractions along the West Coast of North America, and particularly within the Columbia River basin (Clemens et al. 2017). They are included as a State sensitive species in Oregon and Washington, state-listed endangered species in Idaho, designated tribal trust species, and a species of special concern for the US Fish and Wildlife Service (USFWS 2010b). Roads and road crossings are considered a major factor in their contiguous US declines (Clemens et a. 2017).
- Sculpins (*Cottus* sp.) are ubiquitous and generally abundant throughout rivers inhabited by Pacific and Atlantic salmon. Because they are not targeted in subsistence, commercial, or recreational fisheries, however, little is known about their abundance and conservation status throughout North America. At least one sculpin species is listed under the ESA, and another is considered Endangered in Lake Ontario by the New York Department of Environmental Conservation (NYDEC 2020, USFWS 2020).

CAUSES OF GLOBAL DECLINES AND EFFECTIVENESS OF RESTORATION ACTIVITIES

Main causes of salmon and other fish population declines are habitat impacts from urban and rural development, widespread and largescale hydropower, forestry, fishery, and hatchery practices. Mining and roadbuilding also cause physical (e.g., groundwater and surface waterflows, channel configuration), chemical (e.g., increased sedimentation, metals concentrations), and biological (e.g., changes in aquatic insect composition or fish populations), impacts that degrade salmon habitat. Intact headwaters and wetlands comprise fundamental elements of thriving salmon habitat, and their fragmentation is considered a leading cause of global salmon declines (Colvin et al. 2019). Both long-term small scale and short-term largescale development fragment and simplify the complex physical habitat mosaics upon which all fish and aquatic life depend, introduce contaminants into the environment, and ultimately degrade the biological interactions that support robust fish populations.

Restoration activities to restore salmon, trout, lamprey, and other fish restoration are ongoing and extremely expensive. The US General Accounting Office estimates approximately $1.5 billion were spent on Columbia River salmon and steelhead restoration activities from 1997-2001 (USGAO 2002). Multi-billion dollar expenditures continue, although no Pacific salmon population has been removed from the ESA list of threatened and endangered species.

Expenditures include salmon hatcheries, which ultimately lead to decreased survival of wild populations (Naish et al. 2008, Ruggerone et al. 2010). Consequently, many argue that protecting currently intact watersheds is fundamental to the conservation of salmon and many co-occurring fish species on a global scale (e.g., Lichatowich et al. 2000). Western Alaska and Yukon Territory watersheds support the most remaining unfragmented habitat, and some of the largest remaining salmon runs on the eastern side of the Pacific Ocean. To date, virtually no hatchery activity has been conducted in Bristol Bay as opposed to contiguous US and many other Alaska watersheds.

KVICHAK RIVER PACIFIC SALMON AND OTHER FISHES

SOCKEYE SALMON

Because of their abundance and commercial value, most existing fisheries data for Bristol Bay describe sockeye salmon. The Kvichak River watershed supports about 34% of Bristol Bay sockeye salmon production (or about 17% of the global supply of sockeye salmon; Ruggerone et al. 2010; Figure 5). Spawning has been documented in over 100 separate locations in the Kvichak River (Demory et al. 1964, Morstad 2003). Four sub-stocks and at least 22 genetically distinct populations which all exhibit diverse life history strategies are documented in the watershed (Figure 7). Those diverse life history strategies combined with geography are largely responsible for their genetic variability, as evidenced by distinct river spawning (Iliamna Tributaries and Port Alsworth stocks), beach spawning (some populations of the Northeast Iliamna stock), and Iliamna Lake "island beach" spawning (Iliamna Islands Stock) distinctions (Link and Dann 2018; Figure 7). Of note, all successful spawners in the Lake Clark stock—itself consisting of 7 genetically distinct populations—must migrate both up and downstream of at least one component of the proposed Pebble road corridor (T. Dann, ADF&G, Anchorage, personal communication, Ramstad et al. 2004; Figure 7).

Sockeye salmon spawning activity has been documented and roughly indexed largely by aerial surveys in the Kvichak drainage since 1955. The average range of numbers of spawners observed in streams along the proposed road corridor (usually on single-day surveys conducted from 1955-2002), was 527 to 101,306 while maximum numbers range from 1,860 to a million (Demory 1964, Morstad 2003, EPA 2014). Sockeye index counts are highest in the Iliamna River (average >100,000 spawners), the Newhalen River (average >80,000 spawners), and on beaches in Knutson Bay (average >70,000 spawners, but as high 1 million) (EPA 2014). The largest numbers of sockeye spawning were observed toward the east end of Iliamna Lake, where the proposed road corridor most closely parallels the shore (Figure 8). In addition to the streams closest to the road corridor (as pictured in Figure 8) Lake Clark single day spawner counts averaged 39,556, ranging from 100 to 374,551 from 1955-2002 (Morstad 2003; not pictured in Fig. 8). Combined, these spawning populations comprise the majority of overall Kvichak River escapement (Link and Dann 2018). Because aerial surveys suffer from high bias and low precision due to variable environmental conditions, limited survey effort, and statistical shortcomings, spawning counts should be considered substantial underestimates of actual population sizes (Bue et al. 1988, Jones et al. 2007, Woody 2011).
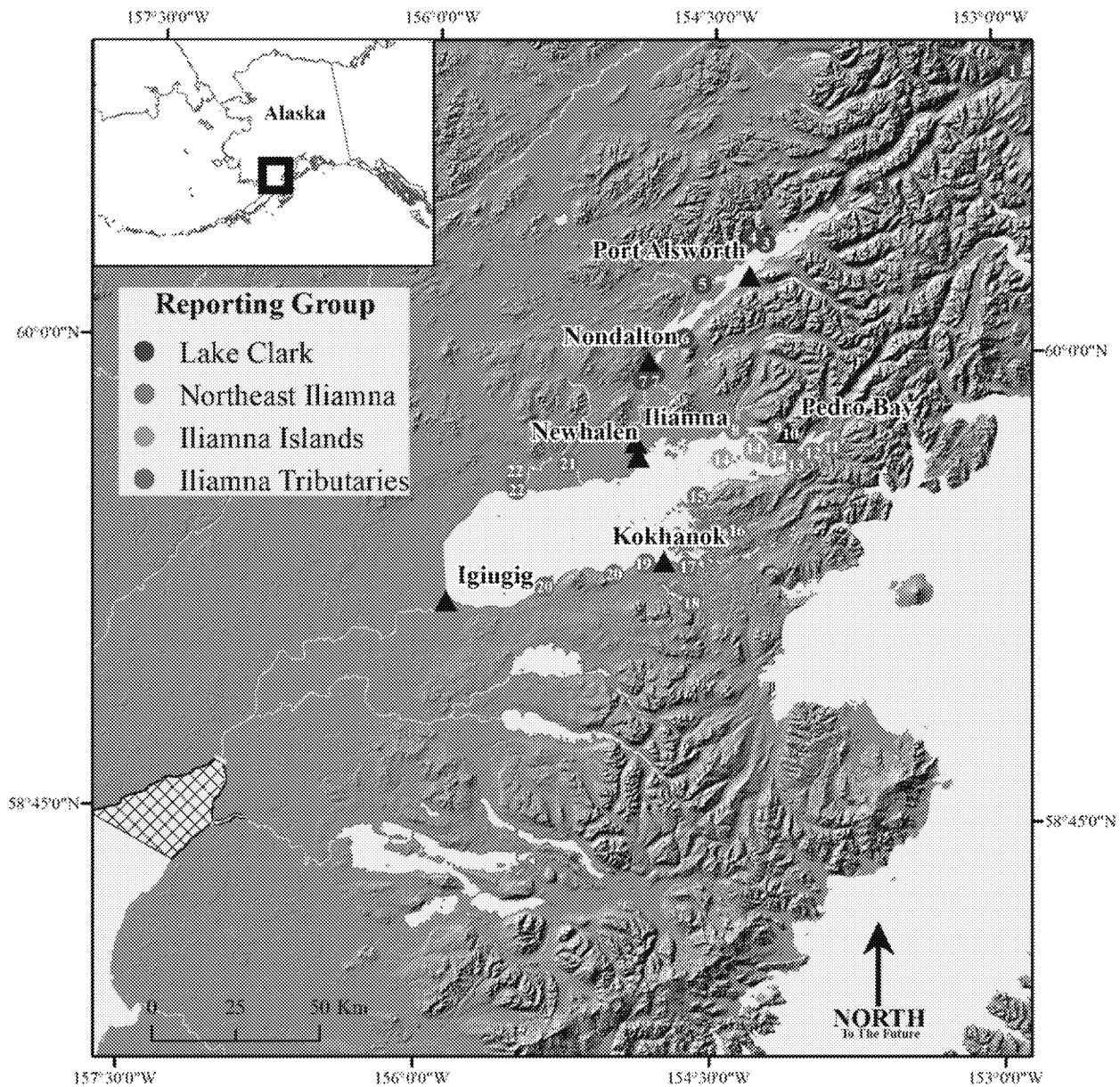
Figure 7. Twenty-two genetically distinct sockeye salmon populations from four individual stock groups (demarcated by color) documented in the Kvichak River watershed, Bristol Bay, Alaska. From Link and Dann 2018.
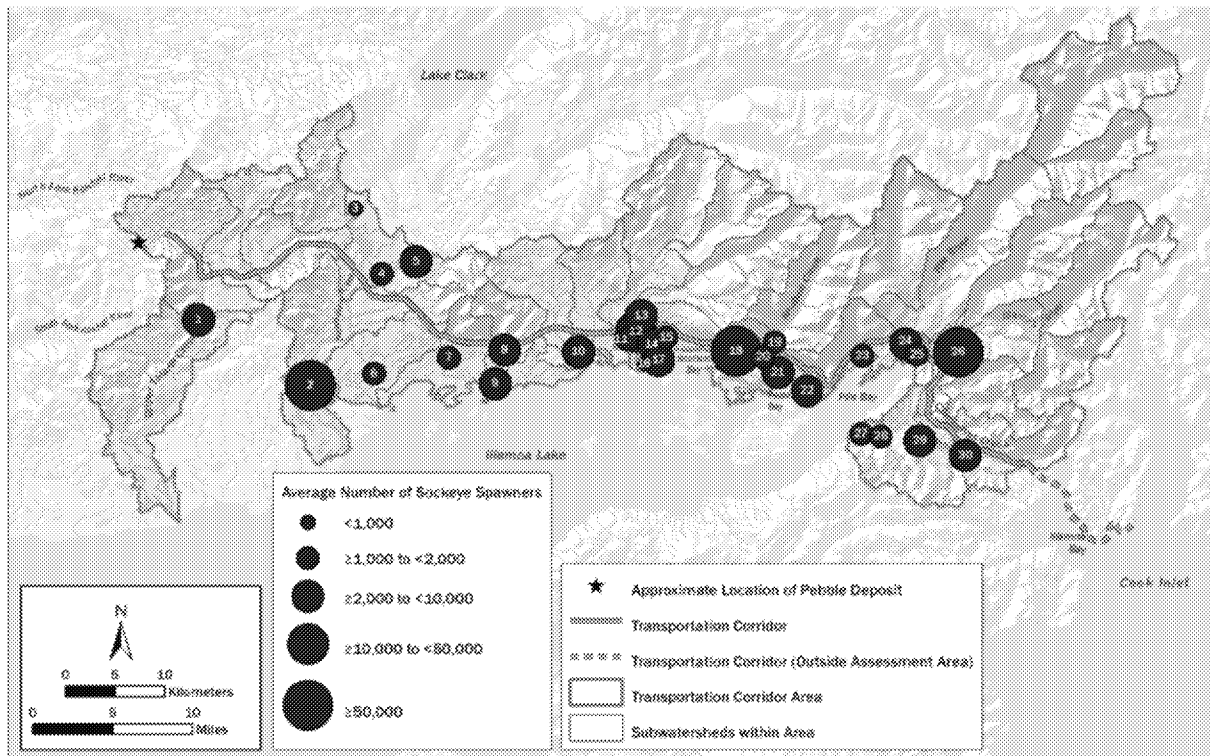
Figure 8. Location of sockeye salmon surveys and average number of spawners observed along the proposed transportation corridor. From EPA 2014 based on data from Morstad 2003.

After adult sockeye spawn and their eggs subsequently incubate over winter, emerged fry typically migrate downstream in early spring into lake habitat where they rear for 1-2 years, feeding largely on zooplankton (Quinn 2018). Freshwater rearing sockeye distribution, production, and genetic composition has been extensively evaluated within Lake Iliamna. The Lake supports the majority of juvenile rearing sockeye in the Kvichak River drainage. Mirroring spawning densities, the highest-density juvenile rearing sites are concentrated on the east end of the lake where the road corridor most closely parallels the lake (Rich 2006; Frissell and Shaftel 2014; Figure 9). In addition to juvenile density, smolts outmigrating from Iliamna Lake have been evaluated for abundance simultaneous with genetic composition in order to estimate relatively productivity of the four substocks. Those data indicate that about half of Kvichak River smolts originate from the NE Iliamna stock group which includes the Iliamna River, Chinkelyes Creek, and Knutson Bay populations—all examples of waterbodies that support large numbers of escapement and will be crossed by or located near the proposed road corridor (Morstad 2003, Link and Dann 2018; Figure 10). Most of the NE Iliamna stock groups spawn and incubate in close proximity to the road corridor (Frissell and Shaftel 2014; Link and Dann 2018; Figures 7-9). About 15% of smolts originate from the Lake Clark stock group—all of which will have to migrate past the road corridor during smoltification, and those that survive to spawn will have to migrate past the road corridor again on their upstream migration.
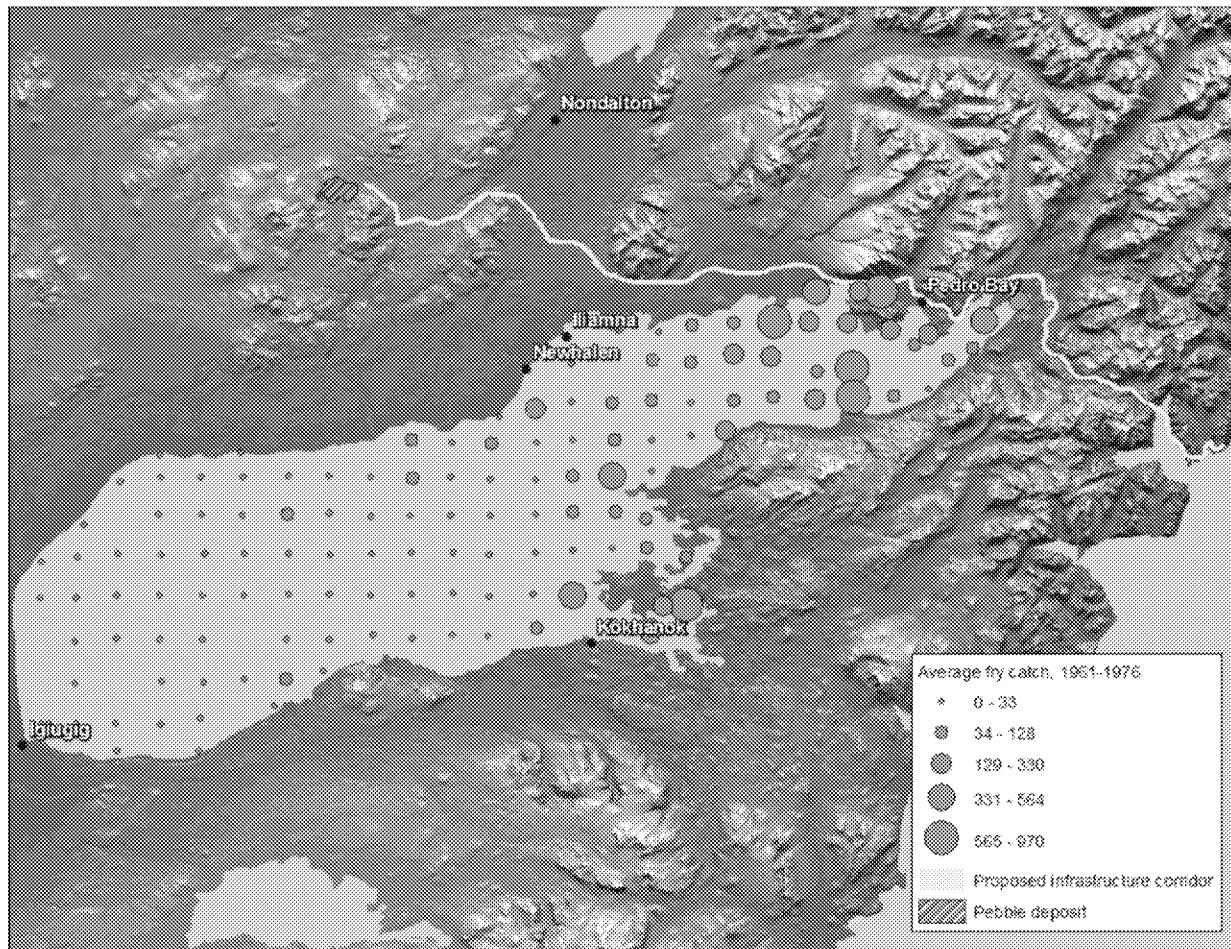
Figure 9. Iliamna Lake juvenile sockeye catches in tow-net sampling, 1961-1976, relative to the proposed transportation corridor. Map from Frissell and Shaftel 2014, based on unpublished data provided by Harry Rich (2011, University of Washington, Seattle, WA).

In addition to variability in spawning and rearing habitat, local geography, and absolute abundance, local stream conditions and life history variation add additional diversity to the sockeye salmon portfolio responsible for the overall sustainability of the Bristol Bay fishery (Hilborn et al. 2003, Schindler et al. 2010; Rinella et al. 2018; Reeves 2000). For example, most juveniles rear for either one or two years in freshwater, and stay at sea for two or three years. Spawners in the same spawning locations also may arrive to spawn at early, later, or middle season.

Mean Annual Smolt Production (2012-2016)
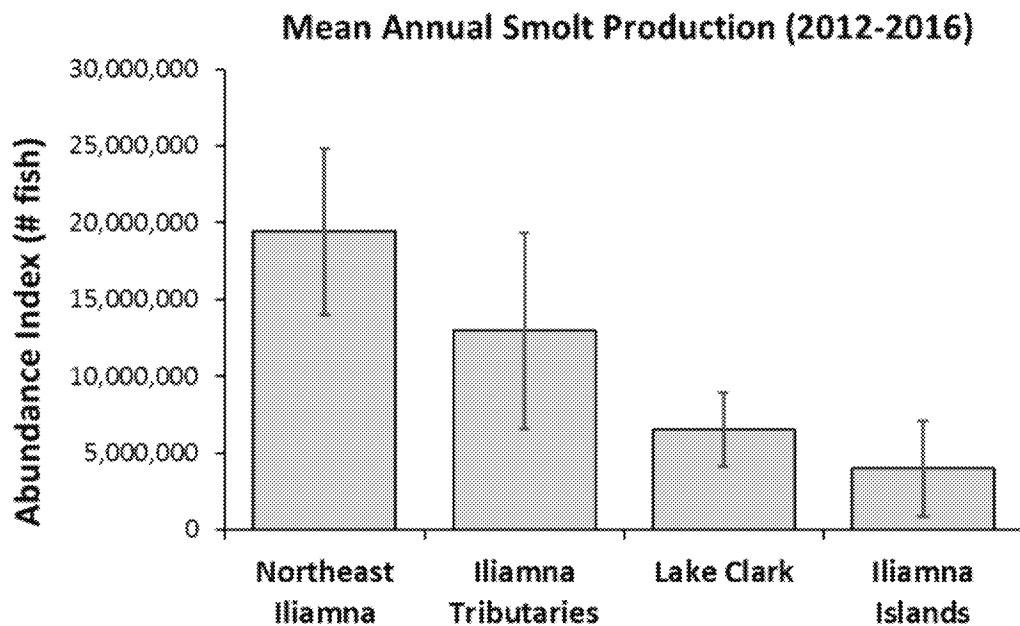
Figure 10. Mean annual smolt production of the four Kvichak River stock groups outmigrating from Lake Iliamna from 2012-2016. Spatial (represented by stock groups) and temporal (represented by error bars) variability highlight the importance of diverse life history and habitat types as well as genetic differentiation in maintaining the overall sustainability of Kvichak River sockeye. From Link and Dann 2018.

OTHER PACIFIC SALMON

Although far less abundant than sockeye, globally unique and valuable species of other Pacific salmon use the Kvichak River drainage, particularly Chinook, coho, and chum salmon. In the contiguous US, over 100 major populations of Pacific salmon and steelhead have been extirpated. Of those remaining, 64 Chinook populations, at least 35 coho populations, and 17 chum populations are considered at some risk of extinction and/or of conservation concerns (Nehlsen et al. 1991). What remains of subsistence and commercial harvests rely on extensive hatchery supplementation which ultimately degrades the overall genetic makeup, fitness and survival of populations (Rand et al. 2012). Bristol Bay is one of the world's only remaining salmon ecosystems that is virtually unaffected by hatchery influence (Figure 4). Far fewer data exist to describe the distribution and abundance of these Chinook, coho, chum, and pink. However, juvenile coho are the second most commonly occurring species found in headwaters draining the proposed mine site and are documented in most of the streams that will be crossed by the road corridor (Woody and O'Neal 2010, PLP 2012, Johnson and Blossom 2019). All five species of anadromous salmon are documented in the Iliamna River—one of the uppermost tributaries to Lake Iliamna which will be crossed by the road corridor—suggesting that those species likely occur in many if not most other tributaries that will be crossed by the road corridor (Johnson and Blossom 2019). Sampling efforts to date are vastly insufficient for thorough characterizations of salmon distribution throughout the area (Johnson 2007, PLP 2012, and others).

OTHER FISH POPOULATIONS

Rainbow trout

For the Pebble Project Environmental Baseline effort, HDR conducted a rainbow trout telemetry study indicating trout documented spawning in spring in Upper Talarik Creek subsequently migrate to several northwest Iliamna Lake tributaries including the Newhalen River (which will be crossed by the road corridor), and the lake itself to overwinter. Rainbow trout also follow spawning sockeye into Upper Talarik Creek where they likely feed heavily on sockeye eggs, producing record-sized rainbow trout popular amongst sport fishermen.

> An adfluvial rainbow trout population exists in Iliamna Lake and its tributaries, including the UT. This population has been the subject of a radio telemetry study monitoring the movements and site fidelity of adult rainbow trout in the UT. Adult trout move from their overwintering areas at the mouths of several northwest Iliamna Lake tributaries into the lake and then into the UT to spawn after ice-out, from mid- May through June. An additional migration of large, adult trout foraging in the UT was documented in late summer. These fish move into the UT with spawning sockeye salmon and subsequently leave to return to Iliamna Lake. Ninety-five adfluvial rainbow trout from UT-A and two trout from UT-C were collected and radio tagged during the study. From May through October, one hundred seventy-seven additional rainbow trout adults were also observed throughout the UT (Appendix 15.1B, Tables B.12-7, B.13-7, B.14-6, B.15-2, and B.17-7). Based on size distributions, these adults represent a mix of post- spawning adfluvial fish and a resident population of rainbow trout. (PLP EBD Ch. 15, p. 15.1-85)

> The lower mainstem Newhalen River is known to support coho salmon, Chinook salmon, sockeye salmon, rainbow trout, and Arctic char (ADF&G, 2010; Map 15.3-3). The Newhalen River rainbow trout population includes an adfluvial component. During a separate radio telemetry study monitoring the movements and site fidelity of adult rainbow trout from the UT, tagged rainbow trout were documented overwintering in the Newhalen River (R2 Resource Consultants, unpublished data). (PLP EBD Ch. 15, p. 15.3-8)

Lake Iliamna rainbow trout exhibit life history (stream-resident, lake-migrant), visible trait, and genetic diversity (Arostegui et al. 2019, Arostegui and Quinn 2019) not unlike the diversity exhibited amongst anadromous Bristol Bay salmon.

Other fishes

- Anadromous **Arctic char** are documented in many Lake Iliamna tributaries, including those that will be crossed by the road corridor. Arctic char an important subsistence species.
- Dolly Varden are the most commonly found trout (technically, char) species in the Bristol Bay and road corridor footprint, and the third most common fish species documented outside of sockeye spawning season (Woody and O'Neal 2010).
- Additional freshwater-migratory and resident fish inhabiting the Kvichak River drainage that are important to subsistence include native Northern Pike (*Esox Lucius*), and freshwater migrant humpback whitefish (*Coregonus pidschian*). Humpback whitefish are the second most important subsistence species harvested in Nondalton Village located near the mine site and transportation corridor (Woody 2018).

- Other important recreational species include widespread Dolly Varden (*Salvelinus malma*), rainbow trout (*Oncorhynchus mykiss*), and Arctic grayling (*Thymallus arcticus*).
- Sculpins (*Cottus* sp.) are the most ubiquitous and generally most abundant fish found in streams draining the Pebble deposit and intersecting the road corridor indicating their prominent role in the aquatic food webs of these small streams. (Woody and O'Neal 2010, PLP 2011)
- Many other fish species critical to the overall aquatic food web also occur throughout the basin, including in rivers and streams that will be impacted by the Pebble Mine access road. Beyond streams outside proposed Pebble Project footprint and along the road corridor, probably 80% of Kvichak River tributaries have never been sampled for fish distribution and non-salmon species habitat requirements, abundance, genetic and life history diversity, and other factors essential to their sustainability (Johnson 2007). Furthermore, sampling along the road corridor which has taken place typically involved only one, short sampling event insufficient to characterize true fish distribution in those streams.

GENERAL MINE IMPACTS

If the Pebble Mine is developed, direct and indirect impacts via habitat fragmentation and alteration to Bristol Bay salmon and other fish populations are inevitable. Impacts are certain to include alterations in ground and surface waterflows and their interactions (Wobus and Prucha 2020), physical habitat alteration and fragmentation, stream temperature and chemistry (Reeves 2020, Soblewski 2020, Wlostowski 2020), and wetland area and function (Fennessy 2020, Schweisberg 2020). Exact changes to salmon habitat and populations are impossible to empirically predict, what the FEIS refers to as "not measurable" (e.g., FEIS ES-p. 102). The FEIS contains errors in water balances (Wobus and Prucha 2020); underestimations of contaminant sources (Wlostowski 2020), wetlands area and impacts (Fennessy 2020, Schweisberg 2020), indirect impacts, mitigation effectiveness (Yocom 2020); and overestimations of water treatment technology Soblewski 2020). Consideration of direct effects in the EIS are largely limited to the physical footprint and close proximity of mine associated infrastructure. It underestimates the importance of headwater streams and wetlands to overall ecosystem function, frequently referring to these pristine environments as "low quality" (e.g., p. 3.24-5, Schweisberg 2020). It fails to consider the extensive upstream and downstream impacts resulting from dust, migration barriers and impediments, and downstream alterations in flow, nutrient and other chemical cycling, and cascading food web effects. By reducing impacts to individual project components and isolated categories, the FEIS dramatically underestimates overall impact to fish and their habitat (see also Lubetkin and Reeves, 2020, Reeves 2020a, and Reeves 2020b, Schweisberg 2020, and others).

GENERAL ROAD IMPACTS

Volumes of literature generated over at least six decades describe far-reaching and long-lasting impacts of roads to fish and their habitat (e.g., Haupt 1959; Furniss et al. 1991, Forman and Alexander 1998, Trombulak and Frissell 2000, Angermeier et al. 2004) including multiple reviews specific to the proposed Pebble Mine project (e.g., EPA 2014, Kravitz and Blair 2019, and other Pebble-related gray papers authored by tribes, public agencies, non-governmental, and

private organizations). Though voluminous, the majority of literature regarding road impacts in Pacific-salmon ecosystems addresses logging and urban roads in the western contiguous United States and British Columbia. Impacts of roads in remote and extreme higher latitudes like those in Bristol Bay are less described, but most likely generate additional impacts due to ice processes and difficult access for maintenance, spill response, and other issues. While very little literature describes the spatial and temporal extent or variability of road impacts, there are general conceptual models describing far reaching and long lasting impacts (Figure 11). While dozens of specific road impacts have been described, most are interrelated, and fall within the broad categories briefly described below.
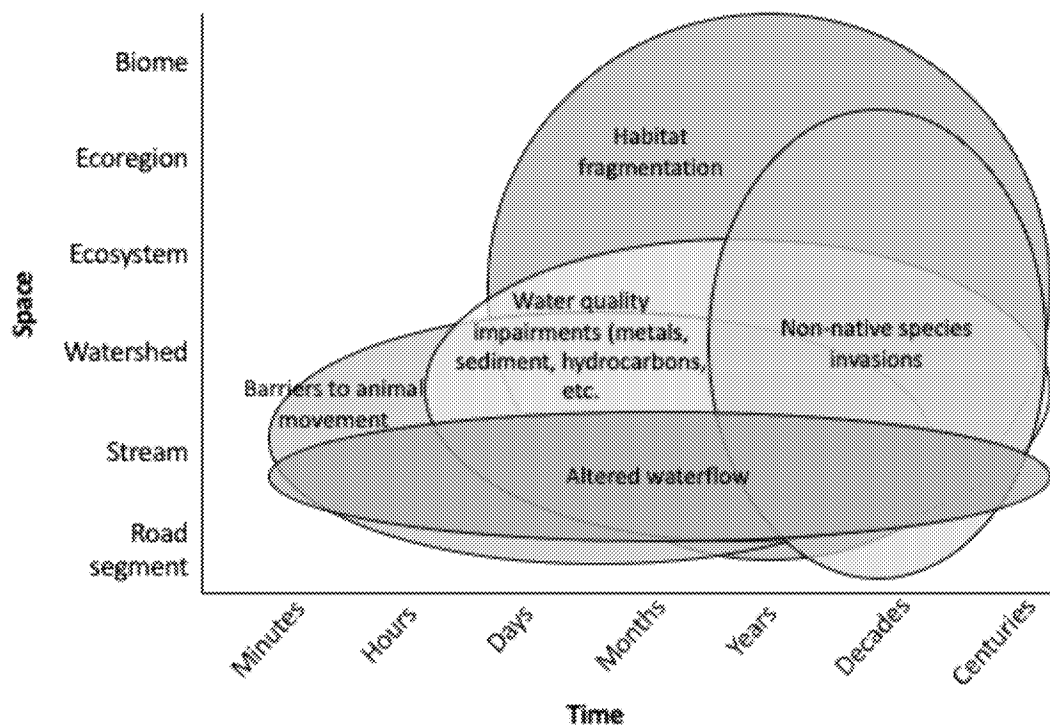

Figure 11. Temporal and spatial dimensions of ecological effects of roads. Adapted from Angermeier et al. 2004 and NRC 2005.

HABITAT SIMPLIFICATION

Particularly in floodplain (but in many if not most) stream habitats, road crossings restrict the migration of river channels across their valley bottom, and thus their connection to riparian, wetland, other groundwater-influenced, and headwater habitats crucial to their overall function (Vannote 1980, Stanford and Ward 1993, Forman and Alexander 1998, Hancock 2002, Colvin et al. 2019; Figure 12). River channel migration creates and manages side channels, pools, surface water and groundwater interactions, and nutrient dynamics, creating the habitat complexity essential to the productivity and sustainability of all native aquatic life (Stanford et al. 2005, Whited et al. 2012, Bellmore Luck et al. 2015, Bellmore et al. 2017). In undeveloped watersheds, channel migration and associated cut and fill of riverbanks and instream habitat, respectively, are further facilitated by beaver and debris dams, and ice processes (e.g., Malison et

al. 2015, J. Stanford personal communication). These natural processes combine to create the complex habitat that Pacific salmon and associated fishes have relied upon for their millennia-long sustainability. Most often, bridge and especially culvert widths do not span the zone of channel migration, in spite of permitting requirements and best management practices. While the up and downstream up and downstream extent of habitat simplification remains difficult to quantify, impacts last for beyond the construction, use, and even closure of roads.
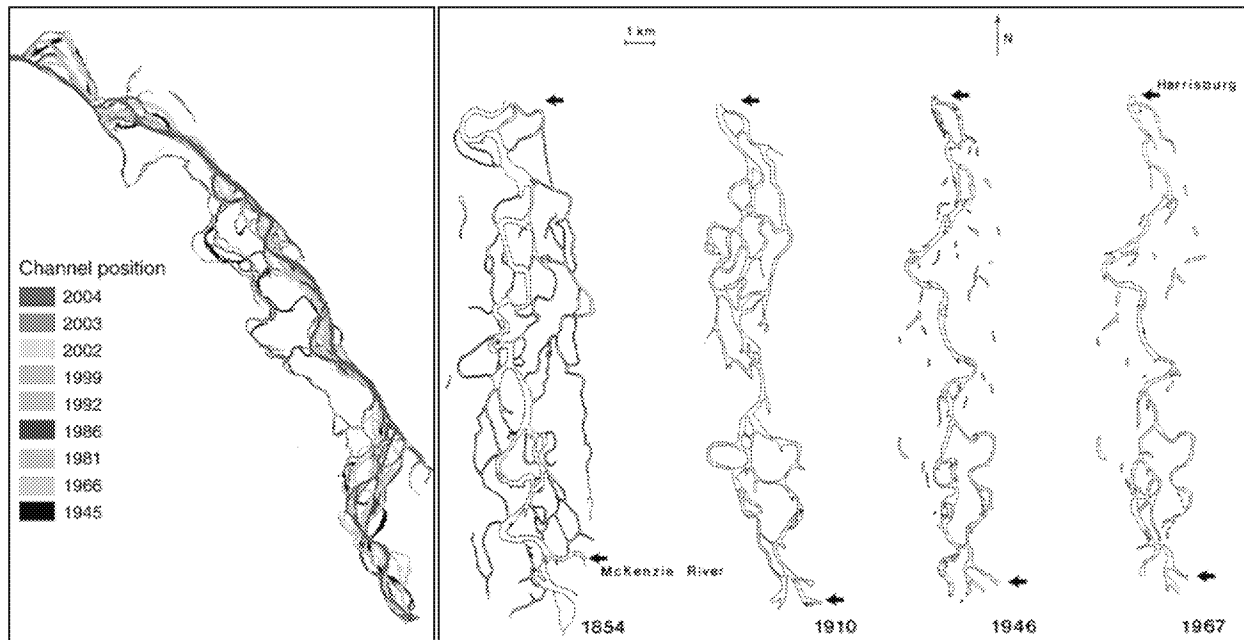
Figure 12. Habitat complexity driven by channel movement over time in the undeveloped Nyack River, MT floodplain (left), compared to habitat simplification driven by development in a Willamette River, OR floodplain (right). Images from Whited et al. 2007, and Sedell and Froggatt 1984.

BANK EROSION AND CHANNEL INCISION

Because streams encumbered by culverts and bridges become disconnected from the valley bottoms they historically migrated across, they often become incised into a channel in which the road crossing structure forces them (Figure 13). This alters stream hydrology (frequently increasing stream velocity), channel structure, and generally leads to increased fine sediment deposition in the vicinity of the crossing (Figure 13). These changes can lead to velocity barriers, lack of resting habitat, and direct loss of salmon spawning and incubation habitat which requires gravel to cobble-sized substrates. The velocity and sediment influences of road crossings can extend about 0.5 km (0.3 mi) upstream and 1 km (0.6 mi) downstream of road crossings (Forman and Alexander 1998), alter groundwater and surface water interactions, nutrient dynamics, and ultimately biological productivity (Figure 14). Impacts would necessarily last until beyond the end of the use of the road.
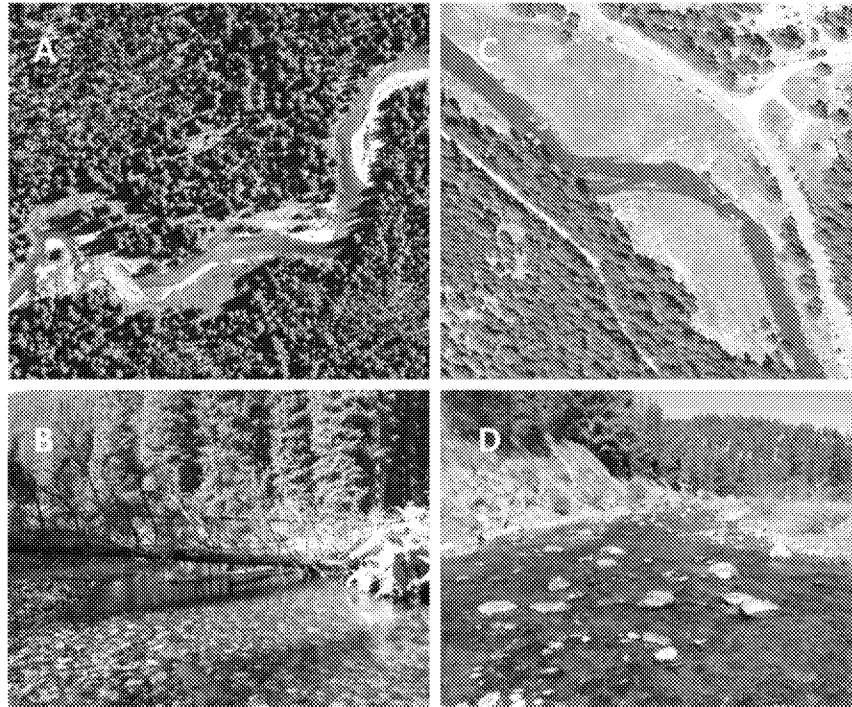
Figure 13. Examples of complex, free flowing habitat in an undeveloped watershed (A, B), compared to simplified, incised habitat in a developed watershed (C, D). The undeveloped stream reach illustrates ideal fish spawning, incubating, and rearing habitat, while that in the developed stream reach is impaired habitat resulting from disconnection from its floodplain, a lack of complexity and shade from riparian vegetation, and imbedded substrates resulting from fine sediment deposition. From White et al. 2017.

MIGRATION BARRIERS

Road crossings frequently become barriers to migratory salmon, resident fishes, and lamprey migration because of physical, chemical, and biological factors (Table 2). In addition to the physical factors described above (habitat simplification, increased velocities and sedimentation), stream crossings may become physically impassable to fish when bridges or culverts are blocked (e.g. with wood, ice, or overflowing water; Figure 15). In one recent evaluation of culverts in Alaska's remote Tyonek and Seldovia areas, more than 10% of culverts evaluated did not implement any best management practices intended for fish passage, and over 60% of culverts had one or more passage and/or maintenance issues (Nudelman 2015). Impacts of blocked migration extend to the upstream and downstream ranges of migrating fish. In the case of Kvichak salmon for example, impacts of blocked migration could extend tens of miles up and downstream, collectively accumulating dozens if not hundreds of stream miles in total. The duration of impact would equal that of the blockage, which could be hours (until inspection during road use) to years (after the road is abandoned).

Table 2. Salmonid and lamprey passage effectiveness in US and Canadian streams

| Location	Species	Culvert passage effectiveness	Citation
Clearwater River, Montana	Westslope cutthroat trout, brook trout, brown trout, and bull trout	76-85% of culverts were migration barriers	Blank et al. 2005
Small streams in west-central Arkansas	21 warmwater fish species	56% of species could not pass	Warren and Pardew 1998
Lab environment	Lamprey species	14-57% could not pass	Vowles et al. 2018
Alsea River, Oregon	Pacific and Western Brook lampreys	Nearly 100% migration barrier	Kostow 2002
Kenai Peninsula, Alaska	Pacific salmon and resident fishes	70% of culverts had at least one issue impacting fish passage	Nudelman 2015
Bristol Bay, Alaska	Pacific salmon and resident fishes	72% of culverts may or were 73% of culverts were unlikely or inadequate to pass fish	O'Doherty 2014
King Cove and Cold Bay, Alaska	Pacific salmon and resident fishes	73% of culverts were unlikely or inadequate to pass fish	Eisenman and O'Doherty 2018
Southeast Alaska	Pacific salmon and resident fishes	59% of culverts were unlikely or inadequate to pass fish	Eisenman and O'Doherty 2020
Tongass Forest, Southeast Alaska	Pacific salmon and resident fishes	66% of anadromous fish culverts and 85% of resident fish culverts inadequate for passage	Flanders and Cariello 2000
North Slope, Alaska	Anadromous broad whitefish and resident fishes	Most crossings present a partial barrier to fish at some or most flows	Morris and Winters 2004
Southern Labrador	Atlantic salmon	53% of culverts impaired fish passage	Gibson et al. 2011
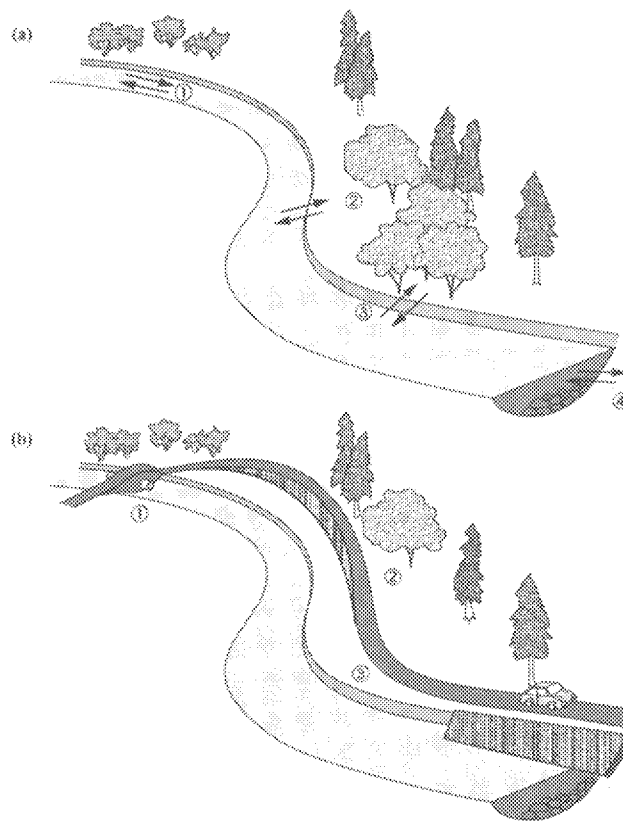
Figure 14. Four aspects of stream connectivity: upstream-downstream (1), floodplain-stream (2), forest-stream (3), and surface-subsurface water connections (4) in an undeveloped floodplain (a), and disrupted by a road in the floodplain (b). From Forman et al. 2003.

Even without blockage, culverts can delay upstream migration by 1-20 days by funneling high flows (and thereby exceeding velocity thresholds), or during low flows (when water depth becomes insufficient) (Lang et al. 2004). Although culvert design has improved with increased consideration for fish passage, passage effectiveness is still mixed, and **depends heavily on information describing species presence and stream flows** which does not currently exist for the proposed road corridor (Chelgren and Dunham 2015). The State of Alaska Highway Drainage Manual itself states that long-term datasets describing year-round streamflow and other physical, chemical, and biological data ideally should last several years (ADTPF 2006). Data for the vast majority of streams along the proposed road corridor have been sampled only once or twice for less than a day, and in some cases less than an hour (PLP 2012 and others). Moreover, even culverts appropriately designed according to modern standards intended to allow for fish passage still fail because:

- Some culverts are still installed incorrectly or improperly maintained,
- After a culvert is installed, stream geomorphology changes, so the culvert design no longer allows fish passage, and
- Opportunities for improving fish passage are lost due to the "emergency" status of culvert replacements following a flood or other culvert failure (Lang et al. 2004).

The remote and frequently frozen nature of the Bristol Bay watershed will only complicate the challenges inherent to all road and culvert maintenance (Figure 15).
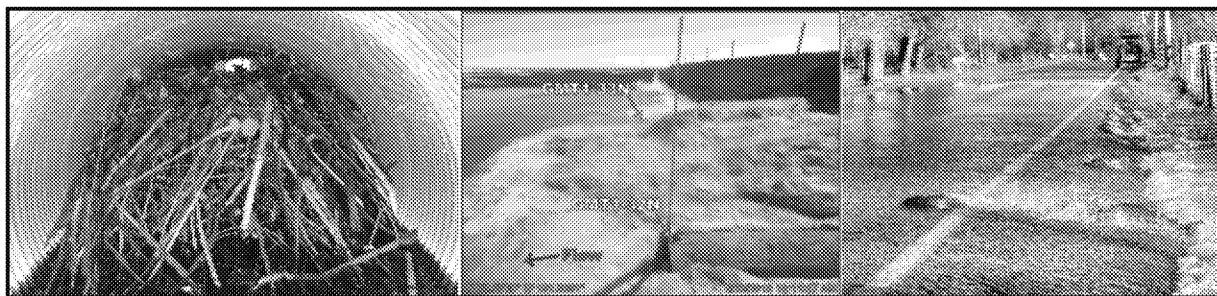
Figure 15. Examples of common causes of culvert blockages: beaver activity (left), ice on Alaska's North Slope (middle), and flooding (right). Images from lizottesolutions.com, Michael Baker International 2019, and thurstontalk.com.

DECREASED WATER QUALITY

Impacts to water quality from roads include: altered temperatures, decreased surface water and groundwater interactions; increased turbidity and, potential acid and metals generation from the road cut itself; and spills, runoff, and dust deposition of metals, hydrocarbons, reagents, and deicing salts; Figures 16-17). Many of these pollutants will deter, impair, or kill migrating salmon and other aquatic species, depending on their concentrations (see O'Neal 2020). Very little existing data describe the spatial extent of these impacts, though acid and metals from road cuts have been documented over 7 km (4.3 mi) downstream of road crossings (Morgan et al. 1984). Impacts likely last at least until the road is decommissioned and revegetated (Forman et al. 2003).
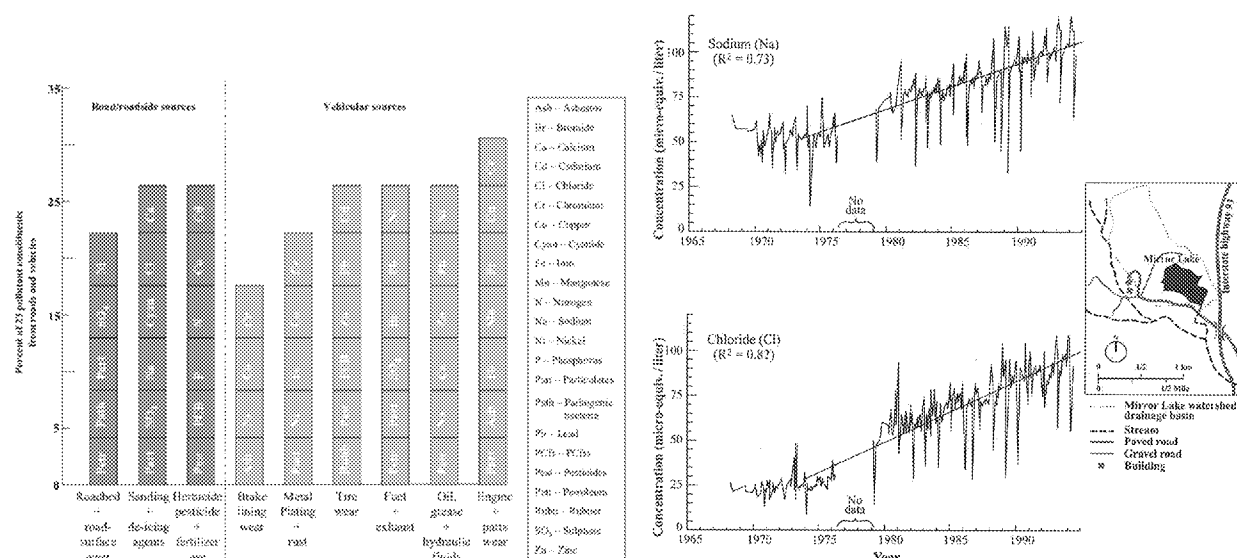
Figure 16. Sources of 23 pollutant constituents in storm-water runoff associated with roads and vehicles (left), and increased concentration of sodium and (top) and chloride (bottom) in a lake affected by a New Hampshire highway 150 m (500 ft) away. From Forman et al. 2003.

Impacts of road-generated pollutants can persist in perpetuity and extend from local watershed-scale to global levels (Figure 17).
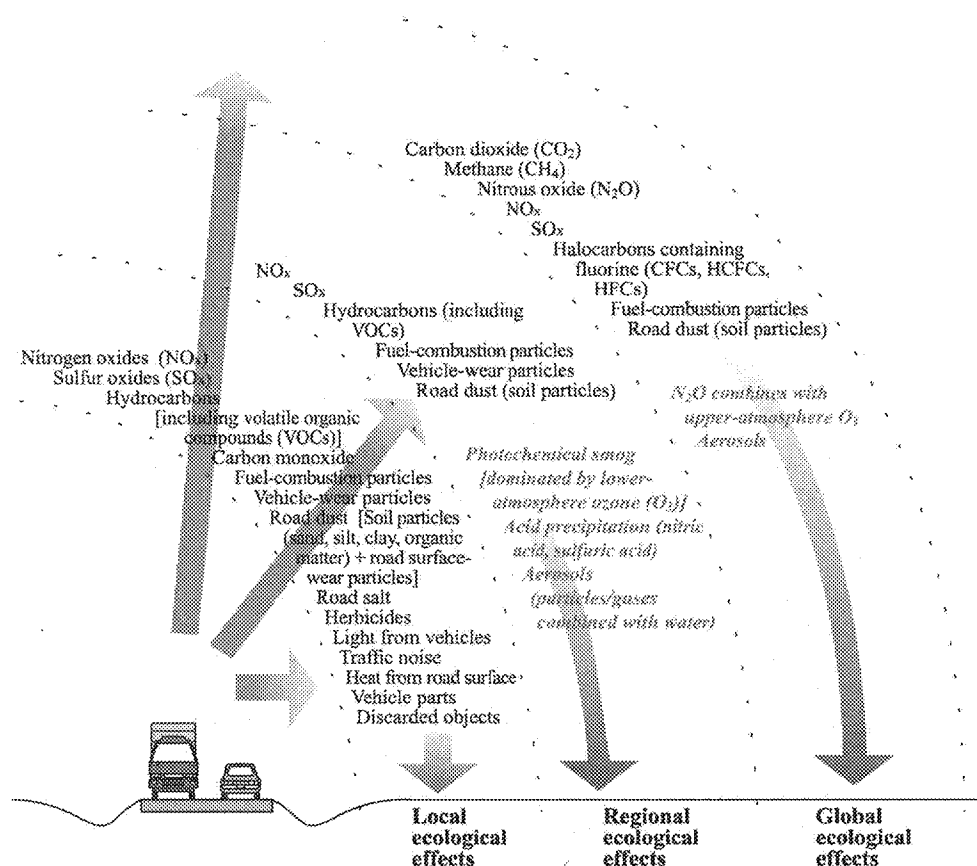
Figure 17. Road and vehicle related pollutants at local, regional, and global scales. The last pollutants (indicated by italics) in the regional and global lists are formed in the atmosphere. From Forman et al. 2003.

INTRODUCTION OF NON-NATIVE SPECIES

Increased human traffic of any kind increases the likelihood of non-native species introduction. Aquatic species of potential concern in the Bristol Bay watershed include terrestrial and wetland plant species which may simplify and alter important riparian habitat (e.g., sweetclover (*Melilotus alba*), Canadian waterweed (*Elodea canadensis*), salmon and other fish pathogens (e.g., whirling disease, *Myxobolus cerebralis*)). The upstream and downstream extent of the impact of non-native species is not known, but could extend at least meters to kilometers from the road corridor. Invasive species inevitably cause cascading impacts to entire terrestrial and aquatic food webs and are considered amongst the largest threats to global species and habitat diversity (Vander Zanden et al. 1999, White et al. 2017). Given the difficulty of eradicating non-native species, impacts would likely last for decades to centuries.

CUMULATIVE IMPACTS

Combined, the impacts of road construction alone will result in permanent, and in some cases global-scale cumulative effects including significantly altered fluxes of water, sediment, nutrients, and complete transformation of multiple river networks and the salmon and all aquatic

life they support (Wohl 2020). While the following figure was created to describe cumulative impacts of the entirety of the Pebble Project, virtually every aspect of it applies to the risks of the transportation and pipeline corridors alone (Figure 18). Each individual impact combined with the overall cumulative effects of the road corridor are vastly underestimated if not completely ignored in the Pebble Project Final EIS. Constructing a 132-km (>82 mi) road in an otherwise roadless will not only fundamentally alter the ecosystem, but will also open it up to expansion of Pebble Mine and development of multiple other claims surrounding it.
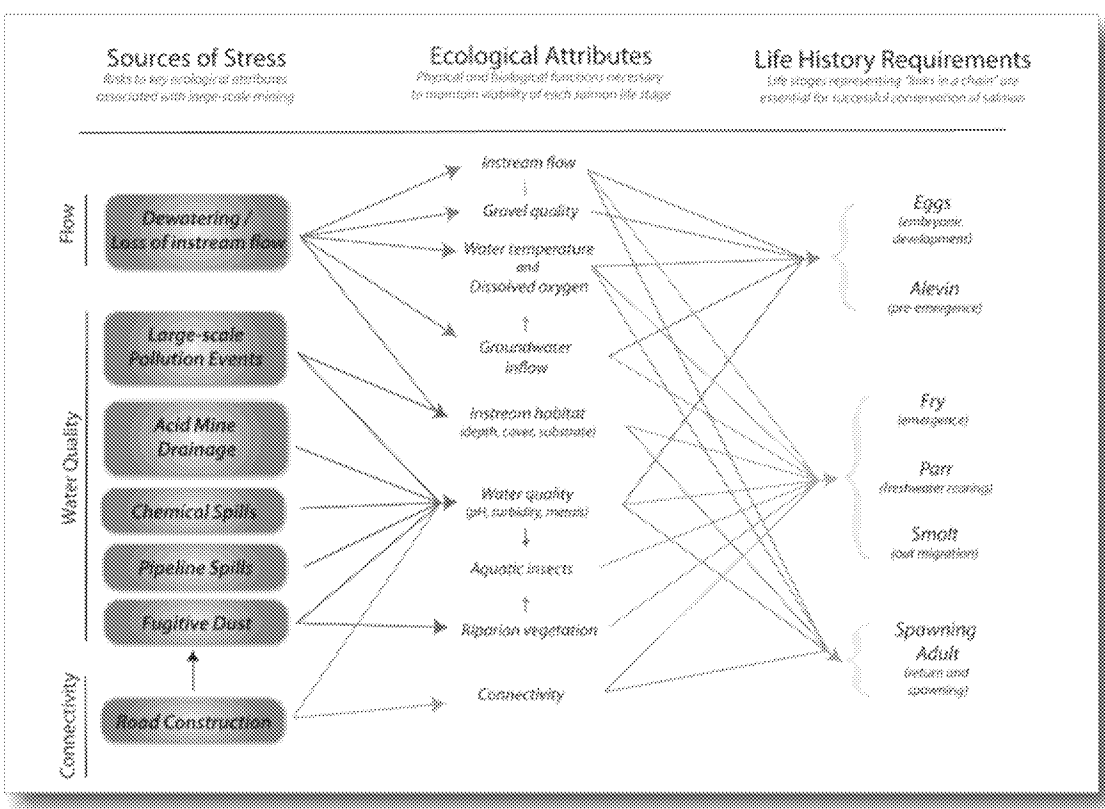
Figure 18. Cumulative effects of road and mine development on Bristol Bay habitat and its resulting impacts to freshwater life stages of Pacific Salmon. Adapted by Dave Albert (The Nature Conservancy) from Ecology and Environment, Inc. 2010.

SPECIFIC SHORTCOMINGS OF THE PEBBLE PROJECT FINAL EIS

By and large, road impacts to aquatic communities are vastly underestimated in the Pebble Project EIS. The EIS concludes that virtually all impacts to fish and their habitat from the transportation corridor will be temporary (limited to days to weeks) and occur within 0.4 km (0.25 mi) within the road alignment. While Furniss et al.'s (1991) influential analysis is nearly three decades old and limited largely to roads constructed for logging, it is still widely cited about all road impacts and concludes that "only rarely can roads be built that have no negative consequences on streams." In fact, he estimated impacts of logging roads had as much as 350 times the impact on stream erosion than logging itself. Darnell (1976) indicated impacts of roads can extend miles from their physical location, and last for decades, Forman et al. (2003) analyze road impacts up a global scale (Figure 17). Specific to the Pebble Project, EPA (2014) conservatively estimated over 30 km of streams, 57 km of wetlands, ponds, and small lakes and

60% of all waterbodies in watersheds crossed by the proposed road are within 200 m (just over one tenth of one mile) of its corridor, and thus would have significant ecological impacts to those waters (Forman and Alexander 1998, EPA 2014). Because upstream and downstream impacts of roads are documented lasting decades to centuries and up to a global scale, even EPA's (2014) estimation of impact in their Bristol Bay Watershed Assessment is far underestimated.

The remainder of this review addresses examples of specific shortcomings in the main body (Section 3.24, 4.24, and 4.27) and two appendices (Appendix D and K 4.24), of the FEIS regarding fish and the transportation corridor primarily as described for the Preferred Alternative (Alternative 3). While not an exhaustive review, it provides many examples of how the ultimate conclusion of the FEIS indicating no measurable impact to fish populations is unsupported in the body of the document.

CHAPTER 3.24 FISH VALUES

In general, the characterization of fish values in Chapter 3.24 greatly exaggerate the state of knowledge and data describing the habitat that will interact with the road corridor. In many cases, streams were surveyed only on one occasion, and sometimes for less than an hour. Given the long-term and far-reaching impacts of road construction far more information would be necessary to predict or measure habitat changes.

p. 3.24-3:

"Some of the larger lakes provide spawning habitat for sockeye salmon."

Comment: Many if not most of the lakes provide sockeye spawning habitat (e.g., Pickerel Lakes, so-called Wiggly Lakes, etc.; Johnson and Blossom 2019).

p. 3.24-3:

> Extensive biological surveying was done in freshwater and marine habitats potentially impacted by project development. Habitat components were assessed throughout the mainstem, tributary, and off-channel habitats surrounding the mine site and at proposed road and pipeline crossings... however, given the high intensity of biological sampling in the project area, the survey results are considered representative of fish distribution and habitats in the analysis area.

Comment: Biological and habitat surveys were not extensive or remotely adequate at proposed road and pipeline crossings. Most streams that would be crossed were sampled only once or twice for less than a day and in some cases less than an hour for fish, and stream flow and water quality were measured no more than a dozen times in each stream, and in for some streams, only once or not at all (PLP 2011, PLP 2018, RFI 085). Consequently, the assumption of representativeness is scientifically unfounded and leads to underestimation of impacts to fishery areas.

p. 3.24-67, Table 3.24-14:

> Anadromous waters crossed by Access Roads and Pipeline Along Alternative 1a, Alternative 2, and Alternative 3 Transportation Corridor and Natural Gas Pipeline Corridor

Comment: Surveys and other available information are insufficient to accurately describe anadromous fish distribution and continuous flow conditions essential to appropriately design stream crossings for fish passage. Anadromous lamprey were not identified to species or to determine anadromy, and are overlooked entirely (PLP 2011, Johnson and Blossom 2019). Moreover, the full migratory range of other freshwater resident fishes are not considered, including rainbow trout, Dolly Varden, Arctic grayling, or any species of whitefish despite their being documented in multiple places along the preferred road alignment (PLP 2011, Johnson and Blossom 2019).

p. 3.24-69-70 regarding Aquatic Invertebrates (insects):

> The sampling locations are representative of streams in the Bristol Bay drainage. The transportation corridor study area extends eastward beyond the Bristol Bay drainages into the Cook Inlet drainages… However, there are insufficient data from this study area to statistically define trends or relationships with respect to particular sampling method variability, or timing of sampling.

Comment: Sampling for aquatic invertebrates occurred 0-2 times in streams crossed by the preferred road corridor (PLP 2011). Methods were mixed, inappropriate indices were used (in particular, the ASCI index developed for Cook Inlet streams which is not translatable to Bristol Bay), and sampling is both spatially and temporally inadequate to detect any future impacts from road and pipeline construction and operation. This is recognized in the second clause of the FEIS text above, though its significance with respect to the inability measure impacts from the road are not mentioned. Moreover, at least one-third of mayfly, stonefly, and caddisfly taxa were misidentified in PLP environmental baseline studies, which is particularly significant given their importance in detecting trends in habitat degradation (Karr and Chu 1999, O'Neal 2012).

p. 3.24-70:

> Periphyton metrics [collected at only two creeks crossed by the preferred road alignment] for the 2004 data were based on the taxa identifications. Taxa richness was greater for Y Valley Creek than for the unnamed creek (17 and 8 taxa, respectively).

Comment: Periphyton are another useful indicator of stream health (Karr and Chu 1999). Samples from two streams on one occasion each are insufficient for characterizing baseline condition, much less measuring future impacts of road construction and operation. Moreover, the limited number of taxa identified suggest extremely poor taxonomic resolution at best, and erroneous identification at worst.

p. 3.24-73:

> Of the anadromous salmonids, sockeye is the most common species in Iliamna Lake, where they are known to use shoreline habitat for spawning (EPA 2014), particularly in the northeastern portion of the lake (Figure 3.2 4- 19). Juveniles also immigrate into the lake from spawning tributaries to use lacustrine rearing habitats. Iliamna Lake is also heavily used by adfluvial rainbow trout, which use a variety of lake habitats for summer foraging (PLP 2018b; Minard et al. 1992).

Comment: This statement overlooks the proximity of the road corridor to spawning and rearing locations of sockeye salmon in Iliamna Lake. In doing so, the FEIS again underestimates road impacts to sockeye and other fish populations.

CHAPTER 4.24 FISH VALUES

p. 4.24-1:

> …loss of habitat is not expected to have a measurable impact on fish populations downstream of the mine site because these narrow, steep, higher-gradient streams have lower habitat values and low fish densities compared to downstream reaches.

Comment: This statement resembles many others made in the Pebble Project EIS with respect to fish habitat. It underestimates the importance of headwater streams to both their direct value as salmon habitat as well as their importance to shaping downstream habitat.

p. 4.24-1:

> The PFEIS analyzed the aquatic habitat "within 0.25 mile of [transportation] infrastructure," with the understanding that "that many fish species have a much larger range than the analysis area, however, [impact analysis] focuses on fish species and habitat that have a potential to be affected during project construction, operations, and closure.

Comment: Metals mixtures, depressed pH, and elevated dissolved solids generated by exposure of mineral-rich rock surfaces necessary for road construction is documented over 7-km downstream of road crossings (Morgan et al. 1983). Forman and Alexander (1998) additionally estimate hydrologic impacts of stream crossings to extend over half a kilometer (0.3 mi) upstream, and about a kilometer (0.6 mi) downstream, and sediment impacts to extend more than a kilometer downstream. Migration related impacts can extend even further.

p. 4.24-33:

> The PFEIS further predicts no impacts to water temperature or chemistry from roads, and only temporary impacts to streamflow. In contrast to these conclusions, the PFEIS also accurately states that "the road/pipeline footprint would impact riparian and floodplain connectivity in the 100-year floodplain. This could reduce the input of terrestrial nutrients, thereby affecting downstream productivity. The duration of impacts would be permanent." It goes on to indicate that road construction and use "can result in short- and long-term impacts to streams and drainages from increased surface erosion and deposition of fine sediments; alteration of water

temperature; delays or barriers to fish migration at culverts; changes in stream streamflow and hydrologic processes; and introduction of invasive plant species…Accumulations of fine sediments in streams have been associated with decreased fry emergence, reductions in winter carrying capacity and benthic production, and changes in species composition in benthic invertebrate communities.

Comment: While accurate, these statements are in direct contrast to the PFEIS overall conclusions of temporary impact. The document maintains that permit restrictions, best management practices, routine inspection, and mitigation measures will alleviate impacts of culverts, though the literature contradicts those conclusions. Moreover, sufficient mitigation measures are not described in the document and their effectiveness elsewhere is largely unknown/undocumented. The few studies evaluating "modern" North American culverts indicate failure to maintain fish passage in about 30% to over 95% of culverts evaluated, for various reasons (Harper and Quigley 2000, Chestnut 2002, and Gibson et al. 2005, Price et al. 2010). Watershed and stream fragmentation from road crossings can eliminate and/or isolate populations that exhibit unique spawn timing and/or spawn site fidelity, thereby maintaining the genetic, life history, and habitat diversity essential to the overall sustainability of the population (Schindler et al. 2010, Gomez-Uchida et al. 2011, Quinn et al. 2012, Brennan et al. 2019).

p. 4.24-35:

> Potential impacts on fish passage are not expected to occur at stream crossings, except temporarily during construction.

Comment: These statements are contradicted by the best available science described herein or elsewhere.

p. 4.24-26:

> Habitat at the immediate location of culverts would be altered, but fish would continue to use the streams.

Comment: These statements are contradicted by the best available science described herein or elsewhere. As described above, culverts can block up and downstream fish access, effectively eliminating miles of stream habitat. The FEIS fails to take these impacts into account.

p. 4.24-47

> The **Portfolio Effect** is an observation that the Bristol Bay salmon run is produced from an abundance of diverse aquatic habitat; this diversity allows for a harvestable surplus even when some systems experience low abundance (Schindler et al. 2010). The term "Portfolio Effect" is taken from the concept of investment portfolios, where adding to the diversity of investments is thought to reduce risk (or the likelihood of occurrence of losses to the overall investment portfolio, even if some individual investments do not do well). Any loss of salmon production would have an effect on the Bristol Bay "portfolio," similar to the way that financial losses by individual investments would have an effect on an investor's portfolio. In this EIS, the effect to the Bristol Bay portfolio is considered by evaluating the amount of habitat and salmon production that would be lost. No long-term measurable changes in the number of returning salmon are expected, nor is genetic diversity expected to change; therefore, the impact to the Portfolio Effect would not be discernable.

Comment: This description of the so-called portfolio effect is a fundamental misinterpretation of the term which actually applies to the **conservation** of biologically relevant diversity (i.e., diverse habitats, genetics, and life histories within each species) which dampens the overall all effect of **naturally** low abundances in some tributaries in some years, and **naturally** higher abundances in those same tributaries in other years depending on environmental conditions (see Reeves 2020). It is indeed this very fluctuation of habitat and population fluctuations the create the overall sustainability of Bristol Bay's fisheries, and which will inevitable help buffer upcoming impacts of climate change. Any deliberate removal of tributaries removes any opportunity for that to remain or become critical habitat in the future. Brennan et al. (2019) illustrate this expertly.
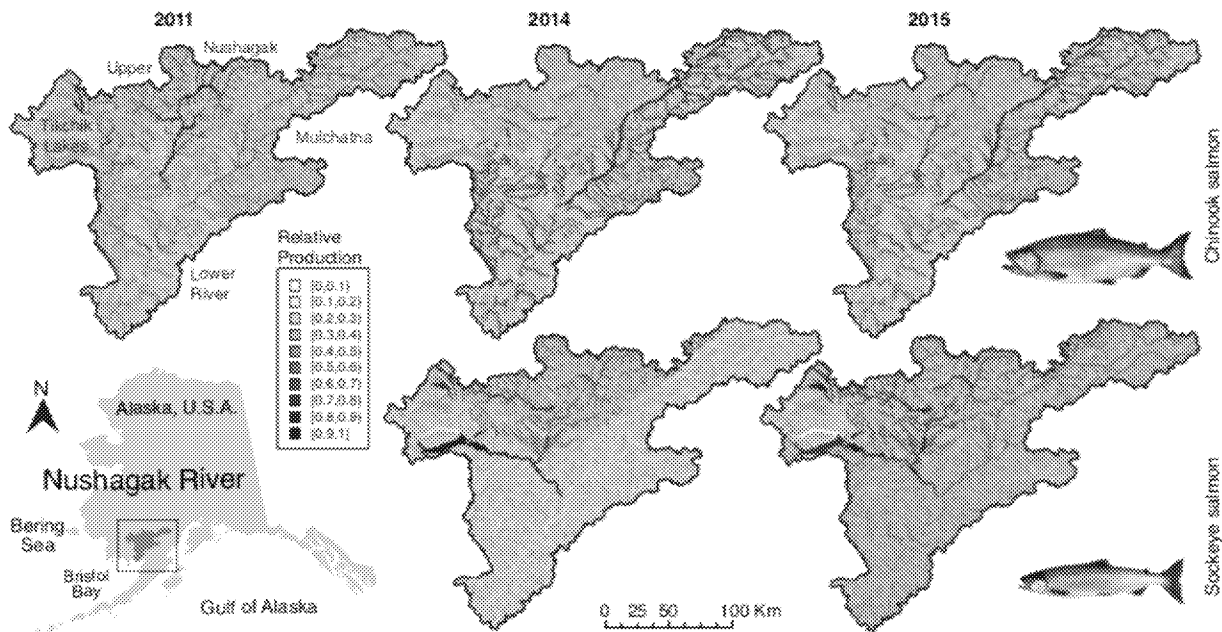
Figure 19. Productive habitats for salmon shift across river basins in the Nushagak drainage. Areas of high Chinook salmon production in (top panel) shifted from the upper Nushagak River to the Mulchatna River in 2014 and 2015. Sockeye salmon production was concentrated in Tikchik lakes in 2014 but was more evenly distributed in 2015 including across riverine habitats. From Brennan et al. 2019.

p. 4.24-29:

> Water withdrawals from multiple locations along the transportation corridor are planned for dust control and hydrostatic testing. "Fish would not be expected to be exposed to injury, displacement, or mortality due to water withdrawals [along the road corridor].

Comment: Discharge, temperature, chemistry, other physical habitat data, and biological data of any utility for predicting or measuring road impacts are extremely limited in the Kvichak watershed, and don't exist for many streams. Furthermore, without injury, displacement, or mortality, fish can still suffer sublethal impacts from decreased streamflow and associated increased temperatures which can ultimately affect their reproduction and survival.

p. 4.24-38:

> While the PFEIS does describes limited food web-mediated indirect impacts of stream crossings resulting from the loss of riparian vegetation, it concludes that "additional non-impacted riparian habitat is available throughout the watersheds," suggesting fish adapted to specific habitats over millennia will simply relocate..

Comment: There is virtually no science—best and/or available—to suggest that distinct populations relocate or otherwise adjust to alternate habitats. In fact, salmon tend to return to within meters to kilometers of their birthplace to spawn. This is what maintains the genetic and life history diversity (two major components of the portfolio effect) that generates the overall sustainability of Bristol Bay's fisheries.

4.24-62:

> The cumulative effects analysis area for fish includes the project footprint, including alternatives and variants; the expanded mine scenario footprint (including road, pipeline, and port facilities); other reasonably foreseeable future actions (RFFAs) in the vicinity of the project that would result in potential synergistic and interactive effects; and the extended geographic area where direct and indirect effects to fish could be expected from construction and operations. This area includes watersheds and downgradient aquatic habitat, from streams to marine waters.

Comment: While this is one of very few instances in which the FEIS refers to downstream impacts of the mine and associated infrastructure, it fails to estimate or predict the extent of those impacts entirely, and neglects *upstream* impacts inevitable from migration barriers created by road crossings. When upstream migration is impeded due to inadequate baseline data collection for appropriate design and inevitable crossing failures, marine derived nutrients from spawning salmon will be prevented from delivery, and freshwater fishes may be prevented from moving up and/or downstream with cascading effects on freshwater food webs.

CHAPTER 4.27 SPILL RISK

p. 4.27-56

> Unlike the metals in the concentrate solids, the metals in the aqueous phase of the slurry would be dissolved and bioavailable, to the extent that the slurry could be acutely toxic in a release.

Comment: The FEIS occasionally acknowledges potential for toxic releases along the transportation corridor (and elsewhere). These acknowledgements are not factored in, however, to the general USACE conclusion of 'no measurable impacts on fish.' That conclusion simply is not supported by dozens of statements about spills from the road into waterbodies.

p. 4.27-71

> Potential impacts of the spill [of concentrate from a truck rollover] to fish include decreased success of incubating salmon eggs; reduced food sources for rearing juvenile salmon; modified habitat; and in extreme cases, mortality to eggs and rearing fish. The scope of the potential effects

> to salmon life stages would depend on the timing and magnitude of the spill. The extent of the impact would depend on the downstream dispersal of a small amount (72 ft^3 in this scenario) of concentrate. Mortality to eggs through smothering would be spatially limited. **Future return of an age class could be reduced**. However, this impact would likely be very localized and may not be measurable above natural background variation. The duration of impacts would be short-term, or until the concentrate is dispersed and diluted downstream and/or incorporated into the bedload. (Emphasis added)

Comment: This statement highlights a couple of themes that reverberate throughout the FEIS "analysis" of potential spill and other road impacts which are: 1) that any toxic spills will be diluted to the point of no impact (this holds true in their discussion of hydrocarbons, reagents, concentrates, and sediment despite a lack of examples of this dilution effect on other mining roads); and 2) that impacts to fish are indeed predicted in small, isolated, ultimately diluted instances, but somehow are ignored in the ultimate conclusion of no measurable impacts. While the preferred alternative would transport concentrate in a pipeline, a pipeline spill would undoubtedly have the same or potentially an even worse effect.

p. 4.27-89:

> Aqueous NaHS [a reagent that will be transported by trucks on the road] is strongly alkaline (pH 11 to 12) and very corrosive. NaHS breaks down into hydrogen sulfide (H_2S) at below neutral pH and in the presence of heat. H_2S is highly toxic to fish (EPA 2014).

Comment: While acknowledging the extreme risk of reagent spills on the road corridor, statements of this nature again are simply ignored in the overall conclusion of the FEIS.

APPENDIX D: COMMENT ANALYSIS REPORT

Many previous analyses, comments on prior drafts by cooperating agencies and other commenting stakeholders were ignored wholesale in this Appendix (e.g., EPA 2014, Mouw 2017, Kravitz and Blair 2019, and many others). This ultimately adds to the overall underestimation of impacts from the Pebble Project transportation corridor to fish, their habitat, and the food webs that support them.

APPENDIX K, SECTION 4.24: FISH VALUES

In general, the FEIS has expanded its consideration of deleterious impacts to fish and aquatic life of selenium, copper, cadmium, and mercury compared to previous drafts. While a marked improvement, the discussion fails to sufficiently consider those impacts with respect to project development. Furthermore, it lacks consideration for many other contaminants of concern that will be transported through the pipeline or truck along the transportation corridor including multiple other metals, highly toxic reagents, and hydrocarbons. There is some discussion of toxicity of the reagents and hydrocarbons in the chapter regarding spill risk (4.27) which in fact indicate extreme potential risk to aquatic life and habitat. However, that is not reflected in the overall conclusion of the FEIS.

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